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The Eighty-Fourth Meeting of the American Astronomical Society

By CURVIN H. GINGRICH

At the invitation of Dr. Louis C. Green, director of the Strawbridge Observatory of Haverford College, approximately one-hundred fifty members and friends of the American Astronomical Society convened at Haverford College for the eighty-fourth meeting of the Society on Wednesday, December 27, 1950. A demonstration of the Spitz Planetarium was held in the afternoon for those who arrived early. The Council held its first session at seven P.M., and the registration and assignment of living quarters for guests continued until quite late into the night. This first night proved to be the coldest of the season. Although the thermometer registered no lower than zero, even those, who had come from sections of the country in which much lower temperatures are the rule rather than the exception, felt the penetrating chill. The wintry night and morning became the general topic of conversation at the breakfast table.

After the visitors had partaken of a hearty and satisfying breakfast in the College Commons, the group assembled in the large lecture room in the Haverford Union building for the opening session at nine o'clock. Promptly at the appointed hour, the session was called to order by the President of the Society, Dr. Alfred H. Joy of the Mount Wilson Observatory. Dr. Joy had come directly from Cleveland where he had delivered an address as retiring vice-president of Section D of the A.A.A.S. Dr. Joy introduced the host, Dr. Green, who welcomed the group personally and in the name of the College. Without further ceremony, the presentation of scheduled papers was begun, Dr. Dirk Brouwer presiding during the morning session.

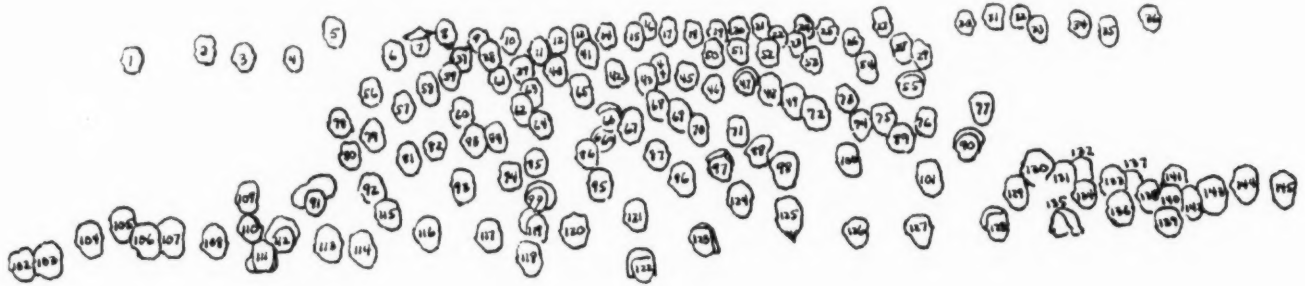
The session was adjourned at twelve in order to provide time for taking the group photograph. The sun was shining brightly and, with Founders Hall, usually referred to simply as Founders, as a background, the result shown in the accompanying photograph was obtained. Luncheon followed, and then, promptly at two P.M., the presentation of papers was continued with Dr. A. E. Whitford presiding.

Between the sessions, the visitors had the use of the facilities afforded by the Haverford Union and by the Common Room, a spacious, well-furnished lounge in Founders Hall, across the quadrangle from the Union. At five P.M., on Thursday, tea was served in the Common Room.

The next event was the climax of the meeting. At eight P.M., the

THE EIGHTY-FOURTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY,
HAVERFORD, PENNSYLVANIA, DECEMBER 27-30, 1950.

(KEY AND NAMES BELOW)



1. Dimitroff
2. Cameron
3. Adams
4. Layzer
5. Irwin
6. Binnendijk
7. Rieber
8. Smiley
9. Dyer
10. Keller
11. Vyssotsky
12. Mitchell
13. Protheroe
14. Deutsch
15. Matthews
16. T. G. Cowling
17. Wildt
18. Sitterly
19. Orral
20. Hoag
21. Wyller
22. Mrs. Merrill
23. Mrs. Henry Smith
24. McKrosky
25. Merrill
26. Henry Smith
27. Bestul
28. Scott
29. Savedoff
30. Yeagley
31. R. H. Wilson
32. Ashbrook
33. Sutton
34. Alden
35. Schopp
36. Heines
37. Weston
38. Harlan Smith
39. Mrs. Harlan Smith
40. Keenan
41. Stearns
42. Sarah Lee Lippincott
43. Munch
44. Mrs. Stearns
45. Miss Roman
46. King
47. Mrs. Gossner
48. Davis
49. Streeter
50. Cuffey
51. Mrs. Sitterly
52. Naqvi
53. Gossner
54. Mrs. Savedoff
55. Mrs. Lewis
56. Leavitt
57. Brouwer
58. Federer
59. Miss Morrow
60. Miss Hutzler
61. Huffer
62. Malitosky
63. Wood
64. Seyfert
65. Blitzstein
66. Miss Reilly
66a. Miss Allen
67. Haddock
68. Hagen
69. Thomas
70. Whipple
71. Harris
72. Eggen
73. Miss Williams
74. Mrs. Mayall
75. Hall
76. Miss Jones
77. Owren
78. Wolff
79. Rabinowitz
80. Hynek
81. Eckert
82. Mrs. Eckert
83. Omer
84. Yoss
85. Miss Weber
86. Miss Underhill
87. Allan Cook
88. Mrs. Whipple
89. Ice
90. Mrs. Menzel
91. Mrs. van de Kamp
92. Mrs. Baker
93. Aller
94. Mrs. Federer
95. Schilt
96. Miller
97. McLaughlin
98. Mrs. Woodward
99. Mrs. Deutsch
100. Goldberg
101. Menzel
102. Barton
103. Whitford
104. Duke
105. Green
106. van de Kamp
107. Baker
108. Chamberlin
109. Spitzer
110. Chester Cook
111. Mrs. Chamberlin
112. Miss Damkoehler
113. Hertz
114. Kameny
115. Kiess
116. Warwick
117. Joy
118. Toni Federer
119. Miss Schwartzman
120. Nassau
121. Robertson
122. Barbara Federer
123. Mrs. Miller
124. Millman
125. Edmondson
126. Miss Barney
127. Schwarzschild
128. Mrs. Schwarzschild
129. Gingrich
130. Miss Swope
131. Stuecklen
132. Kerr
133. Clemence
134. Miss Hill
135. Miss Wright
136. Olivier
137. Bappu
138. Miss Johns
139. Zinszer
140. Yowell
141. Milford
142. Mrs. Owren
143. Epstein
144. Wrubel
145. de Jonge

members and their guests, and a number of local persons, among them members of the Rittenhouse Astronomical Society of Philadelphia, filled the lecture room to overflowing to hear the annual Henry Norris Russell Lecture. Dr. Joy, in introducing the speaker used to good effect a description of the interweaving of his astronomical career and that of the Russell lecturer for the occasion, Dr. Harlow Shapley. He related how they had filled positions in succession at Princeton and again at Mount Wilson. Now (although the president did not make this comment) they were here together as the outstanding personalities at the Haverford Meeting. With a large collection of excellent slides and with his characteristically vivid description and commentaries, Dr. Shapley made this a memorable occasion for every one present. His topic was "The Inner Metagalaxy."

Friday morning dawned bright and sunny overhead but with a treacherous coating of ice underfoot. Fortunately distances between the focal points were short and no casualties resulted. The session for papers, with a brief recess, continued from nine until twelve with Dr. Leo Goldberg presiding.

At two in the afternoon, Dr. Joy called the session to order for the business session of the meeting. He called attention to the importance of keeping the welfare and standing of the Society in mind when recommending applicants for membership. The Secretary, Dr. C. M. Huffer, reviewed the proposed changes in the Constitution which were outlined when the notice of the meeting was sent. By almost unanimous vote of the Society, Sections 2 and 5 of Article III of the Constitution were changed to read as follows:

> SECTION 2. The Council shall consist of the officers, the two available ex-presidents whose presidential terms have most recently expired, provided they have served their full terms, and of nine councilors elected from the membership of the Society. The management of all affairs of the Society not otherwise provided for shall be entrusted to the Council. Each officer of the Society shall be responsible to the Council and shall administer his office in accordance with its instructions.
>
> SECTION 5. The term of office shall be two years for the president, two years for the vice-presidents, three years for the secretary, three years for the treasurer, and three years for each of the nine councilors. The president shall be nominated only from those members of the Society who have served at least one year on the Council. The president, vice-president and the nine councilors shall not be eligible for immediate re-election.

After some discussion concerning the question of life memberships, it became clear that it is very difficult, in view of the lessening value of the dollar, to fix an amount for life memberships that would be reasonable and stable. Consequently, when the question came to a vote it was

decided, again almost unanimously, that no future life memberships be accepted for the present. The president made a brief statement concerning the publication problems now confronting the Society and its members. No definite recommendation was forthcoming and no action was taken at this time. The Secretary then read the list of names of those persons elected to membership in the Society, as follows:

Mr. Edwin A. Beito, 1201 Dreams Landing, Annapolis, Maryland
Mr. Don M. Bubeck, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Mr. Felix Y. K. Chiang, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Miss Mary Lois Connelley, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Mr. J. A. Duerksen, U. S. Coast and Geodetic Survey, Washington, D. C.
Mr. Irving Greenbaum, U. S. Naval Observatory, Washington 25, D. C.
Mr. Fred T. Haddock, Jr., Radio Astronomy Section, Naval Research Laboratory, Washington, D. C.
Mr. Kenneth L. Hallam, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Mr. John Henry Hett, 3140 Netherland Ave., New York 63, N. Y.
Mr. Jack Kent, Box 4355, College Station, Texas
Dr. Karl G. Kessler, 212 South Building, National Bureau of Standards, Washington 25, D. C.
Mr. Paul Kopp, 1305 N. Adams St., Arlington 1, Va.
Rev. Martin F. McCarthy, S. J., Georgetown University, Washington 7, D. C.
Mr. George S. Mumford III, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Mr. Richard C. Nicholas, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Miss Mary W. Peters, Dept. of Physics, University of Tennessee, Knoxville, Tenn.
Professor Leonida Rosino, Astronomical Observatory, Via Zamboni 33, Bologna, Italy
Mrs. Elske P. Smith, Harvard College Observatory, Cambridge 38, Mass.
Mr. Henry J. Smith, Harvard College Observatory, Cambridge 38, Mass.
Dr. A. Victor Stern, 2523 Ridge Rd., Berkeley 9, Calif.
Mr. Thomas L. Swihart, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Sister Mary Therese, B.V.M., Mundelein College, 6363 Sheridan Rd., Chicago 40, Illinois
Mr. Kenneth G. Widing, Goethe Link Observatory, Indiana University, Bloomington, Indiana
Dr. A. J. J. van Woerkom, Yale University Observatory, Prospect & Canner St., New Haven 11, Conn.
Prof. H. L. Yeagley, Penn State College, State College, Pa.
Mr. Harold Zirin, Harvard College Observatory, Cambridge 38, Mass.

Following the business session, the presentation of papers was resumed, Dr. G. M. Clemence presiding.

The time intervening between the close of the afternoon session and the Society dinner was used by many for the purpose of visiting the Strawbridge Observatory and the Haverford College Library. The former, at the edge of the campus, was found to be very attractive in its arrangement, library, and astronomical equipment. In the Treasure Room in the College Library was found the second largest collection of Quakeriana in the world. Of special interest to astronomers were letters by Halley, Rittenhouse, and others. There were also on ex-

members and their guests, and a number of local persons, among them members of the Rittenhouse Astronomical Society of Philadelphia, filled the lecture room to overflowing to hear the annual Henry Norris Russell Lecture. Dr. Joy, in introducing the speaker used to good effect a description of the interweaving of his astronomical career and that of the Russell lecturer for the occasion, Dr. Harlow Shapley. He related how they had filled positions in succession at Princeton and again at Mount Wilson. Now (although the president did not make this comment) they were here together as the outstanding personalities at the Haverford Meeting. With a large collection of excellent slides and with his characteristically vivid description and commentaries, Dr. Shapley made this a memorable occasion for every one present. His topic was "The Inner Metagalaxy."

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hibition such non-Quaker items as a set of the first folio edition of Shakespeare and a page from the Gutenberg Bible. The visitors lingered over these rare exhibits.

Promptly at six-thirty the group assembled in the usual dining room for the Society dinner. The customary sumptuous menu was served. The president, Dr. Joy, presided at the program after the dinner. He announced that Dr. C. E. K. Mees of the Eastman Kodak Company had been elected a patron of the Society. He then introduced Dr. T. G. Cowling of the University of Leeds, England, who was present as a guest of the Society. Dr. Cowling spoke briefly of his impressions of this country and of his plans while here. Following him, Dr. John P. Hagen of the Naval Research Laboratory showed and described a film depicting the circumstances of the Naval Research Laboratory eclipse expedition to Attu, Alaska, for observing the eclipse of September 12, 1950. This proved to be extremely interesting. This was followed by the showing by Dr. John B. Irwin of a number of colored slides made by him in an extensive astronomical pilgrimage through South Africa last summer. The slides and the speaker in his explanations emphasized the work and the setting of the several observatories located there. They also disclosed other incidental experiences of such a journey. Dr. Irwin's success in making the situation realistic is attested by the remark of one who had been there to the effect that he thought he actually was there again.

The after-dinner program was fittingly brought to a close by the reading of a manuscript by Dr. Fred L. Whipple of Harvard College Observatory. In order that nothing of its import and purpose may be lost, the manuscript is given here in full.

The Martian Manuscript

As I was returning from the Friday afternoon session of the American Astronomical Society 1950 Christmas meeting at Haverford, a bundle dropped mysteriously at my feet. I was alone, about to enter the dormitory Building L; apparently the bundle must have fallen from a great height. In my room I lost no time in opening the bundle, to discover that the contents were many sheets of extremely thin and tough transparent plastic, covered with strange characters. With the aid of my pocket microscope I could identify a few of the rectangular characters as minute photographs of our meetings, apparently taken from above with light in the far ultra-violet. A few others showed shadowy figures of our Society members with bright high-lights centered on their foreheads. Probably some unknown mental radiation was exploited in these latter "photographs."

I would have been at a loss for an interpretation except for the fortunate circumstance that the last page contained a glossary of terms in the strange text with some photographs and English words printed alongside. A quick study showed that here was a fragmentary but usable basic dictionary. With great excitement then I hurriedly de-

ciphered as much text as I could in the short interval before the Society Banquet. My free and uninhibited translation follows:

NOTES ADDRESSED TO: COMMANDER-IN-CHIEF OF THE FLAGSHIP "SOARING PLATTER."

Your Royal Flatness:[1]

At your Royal Command I here record my observations of the assembly of heaven worshippers among the Spindle[2] people of Planet Solar-III. I adjusted my body frequency to a value just above their upper threshold so that I might remain unobserved—as per your Royal Order No. 4. Then I adjusted my oscillometer, air-vibration indicator, satisfaction meter, and electromagnetic radiation detector. Unfortunately, my omni-emotion indicator developed a leak so that I could not trust its results.

Incidentally, for your Royal Information, these Spindle people communicate largely by air vibration, but also by body oscillations, radiation, and even by the crude method of physical contact.

I began my observations just at the end of their hibernation period previous to the most recent one. At that time the body oscillometer registered a very high value for the individuals. I first deduced that this shaking of the Spindles indicated great anticipation for the ceremonies soon forthcoming. However, a quick glance at the satisfaction meter showed a low value. I deduce, therefore, that the spindly people were fearful of being disapproved by their companions in the ceremonies. I regret the omni-emotion meter could not have operated to clarify this question.[3]

Next these 6-beings[4] gathered in a large room with many tables where they registered great satisfaction in their peculiar refueling process.

Soon they moved to the ceremonial room where they, one at a time, assumed leadership in their peculiar rites. For a long time I was confused, but it finally became clear, as your Royal Flatness so brilliantly anticipated, that they were worshipping the heavens. However, they spent most of their time making strange air vibrations and placing odd hieroglyphics on the wall. Part of the time they lowered the radiation level and projected these symbols onto the wall. Once or twice a Spindly person directed the attention of the group to the un-radiated portion of the wall as though there were some object there.[5] It was quite confusing; a much longer study will be necessary to comprehend fully their tribal rites.

After about 0.2 of their non-hibernation period had passed, they moved from the ceremonial room to the exterior of one of their buildings where they amassed in close contact. Apparently this rite occurred for the purpose of viewing a couple of short-lived radiation flashes[6]—a procedure that illustrates the futility of their general activities.

At this point I must confess a great indiscretion on my part. In attempting to obtain a closer view I wrapped myself about one of their long immobile complex-carbon compounds which was attached to the ground. In so doing I dislodged some solid compound 1_g-8 almost into the group. They nearly detected my presence but I quickly accelerated my vibration level and remained unobserved.

I will not detail their rites further as little more comprehensible activity occurred. I noted, however, that my satisfaction meter kept registering at a higher and higher level, particularly at the refueling periods and during their less formal ceremonies.

Also, I made some interesting observations of their hibernation habits during the next non-radiation period. They hibernated for a fraction of one radiation cycle equal to 0.26 ± 0.12. It appears that their hibernation habits during the ceremonies are very different from normal, and follow the Fermi-Dirac statistics. I observed only one individual unit per level at this time with certain exceptions and variations of state.

During their hibernation period I confess to another, almost disastrous, indiscretion. Late in the period I weakened in fortitude and adsorbed a bit of delicious element 14 (Silicon). Hence, I necessarily relaxed my high frequency of vibration. As a consequence, much to my chagrin, one of these Spindly beings detected my presence and initiated activity in a large air-vibration device.[1] This aroused a large fraction of the Spindles, but fortunately I kept my presence of mind and quickly raised my vibration level. I believe no harm was done and hope that your Beneficent Royal Flatness will overlook my stupidity.

During the second radiation period the rites and refueling continued unabated. My satisfaction meter indicated greater and greater values. Finally, and I suggest that the scientific instrument division be notified, the satisfaction meter disintegrated from overload. I was forced to return to the "Soaring Platter" with much regret, as I gather that the greatest refueling operation by the Spindle assembly is anticipated in the near future.

Your fat and humble servant,

SPY-PUSS

P.S. I may comment that the heavenly information and understanding of the Spindles appear to be at a low level. At no time in their rites could I detect any reference to our most glorious and magnificent Planet Solar-IV.

NOTES

[1] These beings apparently are shaped something like irregular pancakes. Hence, the highest esteem is accredited to the flattest. I suggest that we call the race the Flatypusses.

[2] My best translation of their term meaning elongated, wire-like, rod-like or skinny.
[3] Editor's note: The morning was bitterly cold.
[4] The number 6 probably represents Carbon. I deduce from later evidence that the Flatypusses are Silicon rather than Carbon beings.
[5] Editor's note: Possibly Dr. Hall pointing at a Pleiades star off his slide.
[6] Editor's note: The group photograph?
[7] Editor's note: An air-raid siren was reported by some members of the Society.

(End of Translation)

A few moments after I had finished the above translation I noticed a cool breeze about my forehead. Suddenly a grayish shadow enveloped the plastic manuscript and it disappeared. Probably Spy-puss had been searching for his lost report and was attracted to me when I came across his name and thought it loudly.

Editor's Note: The comment below was addressed expressly to Dr. Alfred H. Joy, President of the American Astronomical Society.

Mr. President:

I submit that we have here unbiased and conclusive evidence of the great enjoyment and appreciation felt by the members of the A.A.S. for the gracious hospitality that they have met with at Haverford College. I suggest that these sentiments be communicated to the President of Haverford College, to Dr. Green, and to the other members of the college community who made this exceptionally warm and friendly meeting possible.

Fred L. Whipple

After adopting Dr. Whipple's suggestion unaimously and enthusiastically the meeting was adjourned.

The following morning the final session was held at which the remaining papers on the program were presented. At the close of this session the members and friends dispersed, most of them with the hope of reaching home in time to greet the New Year.

Although not officially so announced, coming meetings will probably be held as follows:

Summer 1951, Washington, D. C.; Winter 1951, Cleveland, Ohio; Summer 1952, Victoria, B. C.; Winter 1952, Nashville, Tenn.; Summer 1953, Colorado.

Long-Focus Photographic Astrometry

By PETER VAN DE KAMP

This series of seven chapters is based on lectures given in November and December of the year 1949 at the Institut d'Astrophysique in Paris, on the invitation of Professor Henri Mineur and under the auspices of the Fulbright Act. The subject matter is limited to some

of the photographic astrometric problems which are particularly adapted to long-focus refractors.

An attempt at an introduction to long-focus photographic astrometry, these articles may be of interest to the general reader, and helpful to the student in this field. They have been illustrated mostly by work at the Sproul Observatory. The presentation is not complete; however, representative references are given for further consultation.

The following topics are considered in the different chapters:

1. Observing technique. Telescope, measuring machine.
2. Resolved astrometric binaries. Orbital analysis.
3. Reduction of photographic plates. Dependences. Long-range investigations.
4. Parallax and proper motion.
5. Parallax, orbital motion and proper motion; mass-ratio.
6. Unresolved astrometric binaries.
7. Secular perspective acceleration. Spectroscopic and eclipsing binaries.

CHAPTER I

Observing Technique. Telescope. Measuring Machine

We shall discuss the photographic technique of astrometry, particularly as applied to the accurate positional study of individual objects within a celestial area of small angular extent.[1] Experience has shown that in general, for positional work, refractors are superior to reflectors. We shall limit ourselves to astrometric studies made with achromatic refractors of great focal distance, say over ten meters. The power of these long-focus instruments lies in the large scale portrayal of the observed field in the focal plane.

1. *Rectangular and Equatorial Coordinates.*

There is good reason to study long-focus astrometric problems in rectangular coordinates, and it is customary to use rectangular coordinates x and y, which coincide closely with the directions of right ascension and declination of the equatorial coordinate system. For an extended stellar path, an increasing disparity between rectangular and spherical coordinates will develop which may be represented to a high approximation as a slowly changing orientation of the equatorial with respect to the rectangular coordinate system, amounting to

$$\Delta\theta = + \Delta x \sin \delta$$

where Δx is the projection of the path on the x-coordinate and δ the declination.[2] In comparing, therefore, the results expressed in rectangular and in equatorial coordinates, the above change in position angle should be kept in mind. For an extended path it may imply the well-known secular terms in the spherical components of the proper motion. Its effect on the components of the annual parallactic motion generally is negligible. The secular effects should be considered, especially for stars of large proper motion, situated at high declination, if a conversion

to, or comparison with, the equatorial coordinate system is contemplated.

For an angular extent a on the celestial sphere, the plane extent on the plate, measured from the optical axis, is $\sin a$. Hence a third order "distortion" $a^3/3$ between plane and angular portrayal exists, amounting to 206265 $a^3/3$ in seconds of arc, or $F\ a^3/3$ in linear value. For the case of long-focus refractors the field used is rather small, generally well below one degree in diameter. For an extreme value of $a = 20'$, the distortion amounts to ″.02. In most long-focus problems, a is rather less and the third order distortion may be neglected.

2. *Scale Value. Refraction.*

The scale value σ is usually defined as the number of seconds of arc per millimeter; for a focal length of F mm, the scale value is

$$\sigma = 206265/F.$$

For example, the scale value of the Sproul refractor is expressed by 1 mm = 18″.87, or by the linear value of .053 mm for one second of arc.

A more precise definition of the scale value involves atmospheric refraction. The refraction at zenith distance ζ may be represented to a high degree of approximation by the formula

$$(\mu - 1) \tan \zeta$$

where μ is the index of atmospheric refraction at the observer's location. We write the above relation as

$$R \tan \zeta$$

where R, the atmospheric refraction at $\zeta = 45°$, is the so-called *refraction constant*.

Because of atmospheric refraction any vertical angular distance suffers a minute contraction, whose first order term is represented by the factor $R\ (1 + \tan^2 \zeta)$; any horizontal distance, measured along the great circle suffers a contraction R. For a wide range in wavelengths in the visual spectrum, R is close to 60″, hence the scale reduction in the zenith amounts to .00029. The scale value in use for various telescopes refers to the zenith and *includes* the factor 1.00029 to allow for the contraction caused by refraction. *Relative* to the zenith, there is no additional first order horizontal scale reduction, while the additional vertical reduction due to refraction is given by the term $R \tan^2 \zeta$, which is tabulated below, together with its effect on the Sproul scale value.

ζ	Additional Vertical Scale Reduction	Addition to Sproul Vertical Scale Value
0°	.00000	″0000
10	.00001	.0002
20	.00004	.0008
30	.00010	.0019
40	.00020	.0038
50	.00041	.0077
60	.00087	.0164

In practice, the scale value may refer to the pitch (revolution) of the screw of a measuring engine, this pitch generally being very close to 1 mm or a simple fraction thereof. For example, the scale values at the zenith for the Sproul refractor, according to Strand,[3] are

18″.8733 for the Gaertner machine
18″.8723 for the St. Clair-Kasten machine.

These values vary slightly with the focal setting of the telescope and the observing temperature. Except in special problems, where extreme accuracy may be reached (Chapter 2), the rounded-off scale value 18″.87 is used.

3. *Measuring machine; attainable accuracy.*

The positions of star images in any one coordinate may be conveniently obtained with the aid of a long-screw measuring machine. The plate is mounted on a carriage which can be moved up and down in a plane, at an angle with the horizontal. The plate is viewed with a low-power microscope mounted on a carriage by means of a nut which fits a horizontal long-precision screw having a pitch of, say, one millimeter; by turning the screw and moving the carriage up and down, all portions of the plate may be viewed. The microscope contains a vertical wire (and a horizontal one to indicate the center of the field), for bisecting the star images. At one end the screw is provided with a graduated dial, so that the amount of turning, and hence the distance moved, can be read and recorded to .001 millimeter (one micron). It is customary to carry out averages and further calculations to .0001 mm.

The accuracy of the positions is much higher than the photographic resolving power; the smallest star images are rarely below 1″ in diameter; separation below 1″ is therefore hardly possible. Although the diameters of star images ordinarily range from .04 to over .20 mm, the relative location of two stars may be deduced with an uncertainty which is only a small fraction of the size of the image. With the Sproul refractor, the relative location of two star images is obtained with a probable error of about .002 mm, or less than ″.04. The attainable positional accuracy depends on the formation and quality of the photographic images. The latter depend on several factors, two of which are to some extent subject to our choice, namely:

(a) transparency and focal curve (secondary spectrum) of the objective, and

(b) photographic emulsion and filter.

Additional factors are (c) the selective absorption, and the refraction and dispersion in the earth's atmosphere, (d) the spectra and magnitudes of the stars, and (e) the optical field of the objective.

4. *Focal curve, emulsion and filter.*

In one group of long-focus problems the material consists of photographic plates on which the position of the star that we are interested

in,—the "central" star,—is referred to a "background" of three or more reference stars. The classical example is the parallax work, developed by Schlesinger.[1] Then there is the study of relative positions of the components of resolved astrometric binaries, first developed by Hertzsprung.[4] Both Schlesinger and Hertzsprung had visual refractors; they used panchromatic emulsions and a yellow filter thus eliminating the blue light and obtaining sharp images in the color for which the objective was corrected. Smaller or larger differences in magnitude and spectrum always exist for the different stars; it is of particular importance, therefore, to be aware of the effects on the photographed positions due to the spectra and magnitudes of the stars. As far as the spectra are concerned, the effects are primarily due to our atmosphere, although imperfect collimation of the objective may contribute its share also.

Except at the zenith, each star appears as a spectrum, whose blue end is closer to the zenith than the red end. For stars of different spectral types, the energy distribution is different; moreover, the spectra differ in brightness. For positional work, the spectra should be reduced in order to have as nearly "monochromatic" images as possible; in addition, the brightness of the different stars whose images are to be compared should be reduced to approximate equality. Only in this way may we expect a high degree of positional accuracy. The approach to monochromaticism is obtained by the triple combination objective, filter, and emulsion. Proper choice of filter and emulsion keeps the range of light close to the wavelength corresponding to the minimum focal length of the color curve of the objective.[5] Sharp star images are obtained, as long as the effective radiation is within Raleigh's (visual) criterion for focal accuracy.[6] According to the latter, all images obtained within $4f^2\lambda$ of the focus of a theoretically perfect objective are equally good. In this expression λ is the wavelength that corresponds to minimum focal length, f is the ratio of focal length to aperture. Schlesinger has found by trial with many objectives that the same criterion holds closely for photographs as well. Generally, for long-focus refractors, Raleigh's limit is less than one millimeter.

The photographic position still depends on the residual energy distribution of the star's spectrum, as "filtered" by the objective (transparency and color curve), filter and emulsion. The *effective wavelengths* of these star images depend on the spectrum, and to some extent the magnitude; however, with proper choice of filter and emulsion this dependence may be reduced to a minimum.

5. *Dispersion. Photovisual technique.*

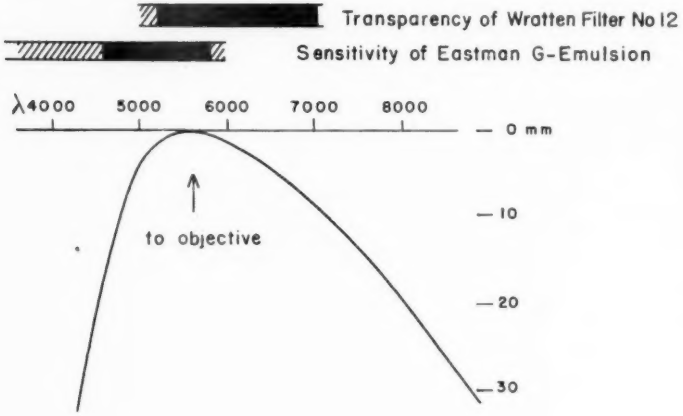
The table below contains for different wavelengths the refraction constant R, together with the dispersion per 100 Å.[7]

λ	R	Dispersion per 100 Å
4000 Å	61″.34	—″.108
4500	60.89	—.072
5000	60.58	—.050
5500	60.33	—.037
6000	60.19	—.028
6500	60.06	—.021
7000	59.96	—.017
7500	59.89	—.014
8000	59.83	—.011

At moderate zenith distances the refraction, and hence the dispersion, varies proportionally to the tangent of the zenith distance.

In conventional photography, using an objective corrected for blue light, a blue sensitive emulsion, and no filter, the effective wavelength is about λ 4300 and is strongly dependent on spectral type. Between spectral types A and K a difference of 200 Å in effective wavelength may exist, corresponding to a difference of ″.18 in the atmospheric refraction constant!″ A much more favorable situation exists in the visual region. We note the rapid decrease of atmospheric dispersion toward longer wavelengths and hence the advantage of the photographic technique as applied with visual refractors,—referred to as *photovisual technique*. Here the effective wavelength is about λ 5500 and a difference of less than ″.02 may exist between the refraction constants for spectral types A and K.

Take, for example, the photovisual astrometric technique as employed with the Sproul visual refractor (see figure). The aperture of the achromatic objective is 61 cm (24 inches), the minimum focal length is



Focal Curve of the Sproul 24-inch Objective

10932 mm for λ 5607.[3] A minus-blue (no. 12) Wratten filter is used in contact with the 5 x 7-inch plate, eliminating practically all radiation on the blue side of approximately λ 5100.[8] A suitable range of radiation is admitted to the photographic plates by using the Eastman G-type emulsion, whose sensitivity is greatest at λ 5650, but extends hardly beyond λ 6000.[9] Hence for the extreme range λ 5100-λ 6000, the vertical spectral extent is only ″.4 at 45° altitude, a value well below the minimum diameter of 1″ for an excellent star image. Even at declination −20°, which represents the lowest feasible altitude at which observations are made at the Sproul Observatory, the (vertical) extent of the spectral image is still below ″.7. For the Sproul refractor $f = 18$, $\lambda = .00056$ mm, hence Raleigh's limit is .7 mm. At the effective wavelength λ 5500, the focal length exceeds the minimum focal length by .1 mm, while for the extreme wavelengths λ 5100 and λ 6000, which still contribute to the formation of the image, the focal length is exceeded by three and one millimeter, respectively. Sharp images are obtained with effective wavelengths ranging only from about λ 5480 for spectral type A to about λ 5525 for spectral type M.[3] This corresponds to a difference in refraction constant of $\Delta R = ″.017$ at an altitude of 45°, the A star being that much closer to the zenith than the M star.

In addition, there is a delicate effect which was first noted by Bergstrand[10] for positions obtained on ordinary photographic emulsions: the photographic position for one and the same spectrum depends somewhat on the brightness. This is explained by the contribution of the radiations of different colors to the formation of the photographic star image. Generally the distribution of these relative intensities is asymmetrical with respect to the wavelength. Initially only a limited range of radiation is effective, while with increased exposure or brightness other radiations begin to contribute to the formation of the photographic image. For one and the same stellar spectrum the relative contribution of the different colors changes gradually with increasing exposure or brightness. The resulting change in effective wavelength or color depends on the character of the color curve and selective absorption of the objective, and on the type of emulsion and filter.

6. *Effect of residual dispersion in right ascension and declination.* Even with the best possible spectral compensation, small differences in effective wavelength are likely to remain. It is advisable to avoid any variation in this residual systematic error, such as would be caused by a large variation in hour-angle. Apart from possible instrumental changes there is the dispersion effect. Let ΔR be the difference in refraction constant, *i.e.*, the dispersion constant for a certain pair of wavelengths. Assuming the refraction, and hence the dispersion, to vary with $\tan \zeta$, the dispersion component in right ascension is given by

$$\Delta R \times \sin t \times \cos \phi \sec \zeta$$

where t is the hour-angle and ϕ the latitude. For observations near the meridian, the formula may be written as

$$\Delta R \times t \times \cos \phi \sec (\phi - \delta).$$

While for observations near the meridian the refraction and hence the dispersion in declination is practically constant, there is a strong dependence on the hour-angle components in right ascension. For observations not exceeding an hour-angle of one hour, the change of the dispersion component in declination is negligible; in right ascension the dispersion effect is very nearly proportional to the hour angle and changes signs at the meridian; an increase in altitude corresponds to a shift toward the meridian. For latitude 45° and $\Delta R = +''.01$ the figures are as follows:[1]

DISPERSION EFFECT IN RIGHT ASCENSION

	Hour angle	60^m E	30^m E	Meridian	30^m W	60^m W
Declination	−20°	−″0046	−″0022	″0000	+″0022	+″0046
	0°	−.0027	−.0013	.0000	+.0013	+.0027
	+20°	−.0021	−.0010	.0000	+.0010	+.0021
	+40°	−.0019	−.0009	.0000	+.0009	+.0019
	+60°	−.0019	−.0009	.0000	+.0009	+.0019

DISPERSION EFFECT IN DECLINATION

	Hour angle	60^m E	30^m E	Meridian	30^m W	60^m W
Declination	−20°	+″0224	+″0216	+″0214	+″0216	+″0224
	0°	.0104	.0101	.0100	.0101	.0104
	+20°	.0049	.0047	.0047	.0047	.0049
	+40°	.0010	.0010	.0009	.0010	.0010
	+60°	.0026	.0027	.0027	.0027	.0026

Variations in the flexure of the objective and possible relative motion of the two lens components may further cause prismatic effects having the same effect as refraction. It is customary to limit the photographic observations as much as possible to the meridian. These hour-angle restrictions are particularly stringent for the ordinary photographic technique, less so in photovisual work.[11]

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CHAPTER II

RESOLVED ASTROMETRIC BINARIES. ORBITAL ANALYSIS

In this chapter we are concerned with the precise technique of long-focus photographic measurements of double stars, first developed by Ejnar Hertzsprung[1] with the visual refractor of 12.5 meters focal length of the Potsdam Observatory during the years 1914 to 1919.

This type of observation has been continued by others, notably by K. Aa. Strand[2,3,4] with the Sproul visual refractor (1938-1942, 1945-1946). Hertzsprung perfected the photographic technique from the beginning and it has been used, essentially unaltered, by his followers. Applied to visual refractors, the use of appropriate emulsion and filter in each case has established a photo-visual technique yielding positional results of extreme accuracy.

The photographic method is limited to wider doubles with separations exceeding about .15 mm on the plate. Below this limit it is, in general, difficult to obtain satisfactory exposures. The neighboring images affect each other, causing either a diminution or an increase in the separation between the images.[5,6] The complexity of the causes of these errors makes it impossible to get anything but a rough estimate of the amount of the various effects, while corrections determined by laboratory experiments are of limited value only. Hence there is every reason to observe the "close" double stars visually, either by micrometer or by interferometer, and to limit the photographic observations to pairs for which the images are clearly separated on the photographic plate.[7,8,9]

1. *Magnitude compensation.*

The so-called magnitude error, due to difference in magnitude between different stars, is caused by coma effects off center and by imperfect guiding of the telescope. In observing the relative positions of the components of a resolved astrometric binary by the photographic method, magnitude error is compensated by the use of coarse gratings in front of the objective. Such a grating produces diffraction images symmetrically located with respect to the central image; these images can be given any desired intensity with respect to the central image by proper choice of the thickness of the bars and of their spacing.

The linear separation, Δ, between the central and nth order images in the focal plane is given by the formula

$$\Delta = nF\lambda/(l+d)$$

where F is the focal length, λ the (effective) wavelength, l the open space between the bars, and d the width of the bar. The extinction in magnitudes for the central image is

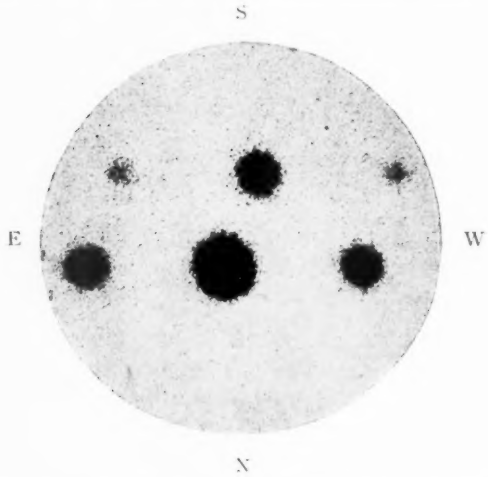
$$5 \log [(l+d)/(l)]. \tag{1}$$

The difference in magnitude between the nth order and central image is given by

$$\Delta m = 5 [\log nl\pi/(l+d) - \log \sin nl\pi/(l+d)]. \tag{2}$$

The diffraction images are really spectra; in the photo-visual technique, however, the first and even higher order spectra look like star images due to the narow range of effective light.

By employing a grating for which the first (or higher) order spectra of the brighter component are of the same intensity as the central im-



A 5-seconds exposure of Castor, enlarged 75 times. The separation of the components is 3″.74 or 0.198 mm on the plate. The first order spectra are one magnitude fainter than the central image. Taken December 1, 1939, by K. Aa. Strand, with the Sproul 24-inch refractor, aperture reduced to 13 inches, Eastman IV G emulsion, Wratten No. 12 (minus-blue) filter.

age of the fainter component, a compensation for possible magnitude error is provided by using the mean of the measured positions of the two spectral images instead of the central image. As long as the difference in intensity between the images does not exceed half a magnitude, the magnitude error is usually negligible; it is therefore sufficient to have a limited number of gratings, producing first-order spectra which are a whole number of magnitudes fainter than the central image. For example, in his work with the Sproul refractor, Strand[3] used four gratings, made of duraluminum, giving differences of one, two, three, and four magnitudes, respectively, between the central image and the first-order spectra. The bars are mounted on 10 cm-wide annular frames, cut from sheets of duraluminum, 3 mm thick. The constants of the four gratings are given below.

Constants of Sproul Objective Gratings

Grating	width of bar	width of opening	extinction for central image	first order minus central image mag. difference	distance
1	11.25 mm	11.21 mm	1.51 mag	.98 mag	.270 mm = 5″.10
2	7.12 mm	15.06 mm	.84 mag	2.05 mag	.273 mm = 5.15
3	3.98 mm	14.80 mm	.52 mag	3.01 mag	.322 mm = 6.08
4	3.20 mm	19.06 mm	.34 mag	3.95 mag	.272 mm = 5.13

2. *At the telescope and measuring machine.*

Continuing with a description of Strand's procedure, each plate has two rows of exposures, in a west to east sequence parallel to the daily

motion; by means of the slow motion, the refractor is given small shifts of about 2 to 3 mm between successive exposures. After a series of about 30 to 40 exposures has been thus obtained, the telescope is given a small shift in declination and the double star itself, or a neighboring bright star, is used to impress a trail giving the equator of the date. As a rule a second row of exposures is then taken, followed by a second trail. Since the exposures are taken without any guiding, the exposure times never exceed 30 seconds; on the other hand, no exposures below 3 seconds are used. The Eastman G-emulsion is used in any one of the types I, II, III, IV, which in about 10 seconds give star images of magnitudes 9, 8, 7, and 6, respectively. For a few bright stars the aperture of the objective is reduced to 33 cm by means of a diaphragm, which also further improves the quality of the images.

The relative position of the two components is obtained from the difference in $\Delta\alpha \cos\delta$ (Δx) and $\Delta\delta$ (Δy), measured on a long-screw machine. In each coordinate the plates are measured with the film turned toward the microscope, and also through the glass, the plate being turned 180° between the two measures around an axis parallel to the vertical bisecting wire in the microscope. This eliminates errors arising from inaccuracy in the orientation between the axis of the screw, the bisecting wire and the motion of the plate at right angles to the screw.

3. *Accuracy.*

For an average plate with 40 to 50 measured exposures, the relative position Δx, Δy of the two components is obtained with a probable error of $\pm$".006. Part of this error, about $\pm$".004, is due to the personal error of the measurer; it affects the distances rather than the position angles. As a rule the error in orientation arising from inaccuracies in the trail is below °.01 for any one plate, and would therefore be less than ".002 for a pair with a separation of 10".

More than a hundred visual observations are required to obtain an accuracy comparable to that of one photographic plate, taken and measured as described above.[4] These visual observations are all independent measures, each representing a single night's observations by one observer, and the mean result is considered made up of observations by many observers with different telescopes. The superiority of the photographic observations is even more pronounced if the distances are considered. The visually observed distances between the components may be off by as much as ".06 even though they are the mean of many observers with different telescopes. It is true that systematic personal errors are not entirely absent in the photographic measures but they are very small and their effect can be partly eliminated by repeated measurements of the same plate by different persons. In the case of visual observations of double stars, systematic and personal errors are appreciable; generally not more than a few repetitions of the settings for a single night's observation, and not more than three or four observations

each year are warranted. With the present photographic technique the systematic errors are much smaller, hence it pays to have 40 to 50 measurable images on each plate and to take four to six plates each year.

4. *Orbital elements.*

The two binary components may be distinguished as primary and companion; both describe similar orbits around their center of mass or barycenter. The orbit of companion relative to primary is defined by the following 7 elements which fall into 3 groups.

1) *dynamical elements:* P (period), e (eccentricity), and T (epoch of periastron passage). For visual binaries P is usually expressed in years, for spectroscopic binaries in days.

2) *scale of the orbit, i.e.*, the semi-axis major or mean distance a, the average of periastron and apastron distance. For visual binaries this element is usually expressed in seconds of arc, but can be converted to astronomical units, if the parallax π is known, by the relation

$$a\ (\text{A.U.}) = a''/\pi''. \tag{3}$$

The dynamical elements P, e, T and the scale a determine the position in the *true orbit.* It is useful to introduce the notion of *unit orbit*—defined by the dynamical elements only, a being now unity—for studying the position in the orbit. The true orbit is similar to the unit orbit and obtained from the latter by applying the scale factor a.

3) *orientation elements:* Ω, ω, and i.

Ω represents the position angle of the "ascending" node, *i.e.*, the point on the intersection of orbital plane and the plane tangential to the sky at the primary, at which the companion approaches us. This property is derived from radial velocity observations. If these are lacking, the ascending node cannot be distinguished and Ω refers simply to that "nodal point" for which $\Omega < 180°$.

ω is the angle counted from the ascending node (or nodal point) to periastron, in the direction of orbital motion.

i is the inclination of the orbital plane on the plane tangent to the sky. For direct motion, i is between 0 and 90°, for retrograde motion $90° < i < 180°$. The sign $\pm$ of the inclination corresponds to that of the radial velocity of the companion (relative to the barycenter) at the ascending node.

5. *Orbital analysis. Position in unit orbit.*

We briefly describe the orbital analysis, generally employed in the case of resolved astrometric binaries for which accurate observations, photographic and others, are available. The same method is easily adapted for the orbital analysis of unresolved astrometric binaries (Chapter 5). First, the dynamical elements P, e and T are derived geometrically, for example by Zwier's method, after which the remaining elements are obtained analytically.[10,11] We introduce the auxiliary circle of radius unity, tangent at periastron and apastron to the true

unit orbit and from which the latter is obtained by the projection factor

$$\sqrt{1-e^2}.$$

Let the directions x and y in the true orbit be defined by the directions to periastron and to anomaly 90°. The position in the unit orbit referred to the focus is then given by:

$$\begin{aligned} x &= \cos E - e \\ y &= \sin E \sqrt{1-e^2} \end{aligned} \tag{4}$$

where E is the eccentric anomaly, measured at the center of the auxiliary circle. The corresponding position in the unit auxiliary circle referred to the center is given by:

$$\begin{aligned} \xi &= \cos E \\ \eta &= \sin E. \end{aligned} \tag{5}$$

The position x, y in the unit obit is derived via Kepler's equation:

$$E - e \sin E = 2\pi (t/T) = M. \tag{6}$$

Here t is the time elapsed since periastron passage, M is the so-called mean anomaly. If the dynamical elements P, e, and T are known, E and hence x and y can be calculated. Tables have been constructed in which the rectangular coordinates x and y are given directly as functions of M and e.[12]

6. *Relation between position in true and apparent orbits.*

The position in the (projected) apparent orbit, can be expressed in the polar coordinates *distance* ρ and *position angle* θ, which are related to the rectangular coordinates as follows:

$$\begin{aligned} \Delta\alpha \cos\delta = \Delta x &= \rho \sin\theta \\ \Delta\delta = \Delta y &= \rho \cos\theta. \end{aligned} \tag{7}$$

It should be noted that the x and y coordinates in the current presentation correspond to the y and x coordinates in the original derivation.[13,14]

The position in the true unit orbit can be expressed in the polar coordinates *radius-vector* r and *true anomaly* v, which are related to the rectangular coordinates in the true orbit through the relations:

$$\begin{aligned} ax &= r \cos v \\ ay &= r \sin v. \end{aligned} \tag{8}$$

The two sets of polar coordinates are related as follows:

$$\begin{aligned} \rho \cos(\theta - \Omega) &= r \cos(v + \omega) \\ \rho \sin(\theta - \Omega) &= r \sin(v + \omega) \cos i. \end{aligned} \tag{9}$$

Working out these relations we find

$$\begin{aligned} \Delta x &= Bx + Gy \\ \Delta y &= Ax + Fy \end{aligned} \tag{10}$$

where

$$\begin{aligned} B &= a\,(\ \ \cos\omega\sin\Omega + \sin\omega\cos\Omega\cos i) \\ A &= a\,(\ \ \cos\omega\sin\Omega - \sin\omega\sin\Omega\cos i) \\ G &= a\,(-\sin\omega\sin\Omega + \cos\omega\cos\Omega\cos i) \\ F &= a\,(-\sin\omega\cos\Omega - \cos\omega\sin\Omega\cos i)\,. \end{aligned} \tag{11}$$

In (10) x and y are functions of the dynamical elements only; B, A, G, and F contain the scale a and the three orientation elements. These four geometric constants are often called the Thiele-Innes constants.

The conventional or Campbell elements are given by the following relations:

$$\begin{gathered} \tan(\omega+\Omega) = (B-F)/(A+G) \\ \tan(\omega-\Omega) = (B+F)/(G-A) \\ \cos i = m/a^2 \qquad a^2 = j+k \\ 2k = A^2+B^2+F^2+G^2,\ m = AG-BF,\ j^2 = k^2-m^2. \end{gathered} \tag{12}$$

The projections on any coordinate R are given by $\gamma_1 a x + \gamma_2 a y$ for the orbit, and by $\gamma_1 a \cos E + \gamma_2 a \sin E$ for the auxiliary circle. Here γ_1 and γ_2 are the direction cosines of the projected coordinates on the directions x and y in the true orbit. Note that $\gamma_1 a$ is the projected coordinate of periastron ($E = 0$), $\gamma_2 a$ the projected coordinate of the auxiliary orbit for $E = 90°$; both coordinates are referred to the center of the orbit. Hence in the equatorial coordinate system B, A and G, F represent the projections of periastron and of the point $E = 90°$ of the auxiliary orbit; these quantities are proportional to the scale a and to the various direction cosines.

7. Application.

The application of the photographic method to double stars, in the hands of Hertzsprung and Strand has made a promising start. In the first place, a number of well-determined orbits have been established for several "classical" double stars, such as η Cas, γ Vir, ξ Boo, 70 Oph. α Gem, and others.[2,15] It has generally been found practical to determine the dynamical elements P, e, and T geometrically from photographic as well as visual normal places, since generally the photographic normal places cover too short a part of the orbit to be used alone. All observations are reduced to the same equator (say 2000) by adding $+°.0056 \sin\alpha \sec\delta\ (2000 - t)$ to the observed position angle at the epoch t: a correction $\mu_\alpha \sin\delta\ (t - 2000)$ is added if the star has an appreciable motion in right ascension. Next the geometric elements B, A, G, and F are determined from a least squares solution based on the photographic normal places alone, using the simple linear formulae (10). The dynamical elements P, e, and T are given slight variations to test the stability of the solution and, if possible, establish a set of elements which give the best fit, as for example, shown by a minimum value of the sum of squares of residuals, O — C. A simultaneous least squares solution for corrections to all seven elements may be made in cases where the available accuracy warrants such a procedure.

8. *Perturbations.*

For several binaries the residuals from the best possible orbit have revealed systematic deviations, which strongly point to a perturbation caused by a third component, close to one of the visible components. While perturbations have been noticed even in visual measures, it is obvious that the chances for discovery are immensely increased with the accurate photographic technique.[16]

The systematic behaviour of the residuals in both coordinates is analyzed for Kepler motion, care being taken to introduce a slight run with the time in either coordinate, providing corrections to the orientational elements of the "large" orbit. After the orbital motion of the "small" orbit has been established, the original observations are corrected for the perturbations and the geometric elements for the large orbit are recomputed. The analysis cannot decide whether the third body is close to the visual primary or secondary component; this can only be decided by referring the orbital motion on an astrometric background of other stars, or, on a system of spectroscopic reference lines from a terrestrial light source.

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(To be continued)

The First Optical Tube

(Astronomical Progress through the Centuries)

By O. S. MARSHALL

The Hale Two-Hundred-Inch Telescope may be the last giant "Optik Tube" to be built. The indications are that electronics will soon enter the astronomical field so long dominated by optical equipment. This recent development in our electrical sciences will undoubtedly greatly extend the scope of research beyond the possibilities of conventional optical methods, and probably there will not be any meteorological handicaps such as limit the work of the telescope. It will not depend on the

darkness of night for its efficiency. Man confronts new horizons, greater dimensions and distances, all of which will mean new astronomical standards of measurement and an intellectual adjustment with the newer knowledge, perhaps of a revolutionary character.

The world is familiar with the tribulations that beset Galileo, when he showed the ecclesiastics his home-made optic tube and persuaded some of them to look through it at the moon and at Jupiter. Galileo perfected the optic tube, which, according to accepted history, originated in Holland about 1600 A.D. The purpose of this discussion is to link the first telescope with the subject of optics. In doing this we shall push back the actual beginnings of telescope making another 500 years, to nearly a thousand years ago. Writers on the history of the telescope do not as a rule go back of the first Dutch-made optic tubes. The crystallographer who holds a crystal in his hand is not satisfied until he knows when, where, and how Nature made that crystal. In our discussion we shall begin with our current astrophysical knowledge and equipment and, from this position, work back to our objective, to an Arab who without question put the knowledge of optics in a form such as the earliest lensmakers could profitably use. From our best knowledge these first lensmakers were spectacle artizans. We shall see that it was by way of the spectacle lens that the telescope came into being.

It will be an illuminating contrast with our own times to state briefly the intellectual conditions at the time when Galileo prevailed upon his skeptical contemporaries to look at the moon through his little telescope which brought that orb three or four times nearer to the eye. "Intellectual smog" was an unknown phrase in Galileo's time which is proverbially spoken of as the Dark Ages. Ecclesiasticism had a firm grip upon most phases of knowledge and its "go and no-go gage system" was diligently applied lest Satan should foist some evil device upon mankind. The earth was the center of the moving spheres including the sun. The earth might be flat or perhaps it was a cylinder. But Aristotle and Ptolemy had rendered their decisions about this and what they affirmed must be true. Other-worldism was the goal and this earth a place to escape from in the quickest way possible. Ecclesiasticism was concerned over how many angels could dance on the point of a needle at the same moment. Mendicant monks and friars meandered about the country in groups living on the labor of honest toilers. At the opposite extreme were the Saint Simeon Stylites who isolated themselves on top of poles thirty or forty feet high for as many years, depending on sympathetic onlookers to throw food up to them. Thus they existed until death by slow personal torture bore their souls at last to paradise. By such torture it was hoped that their incurred penalties might be to some degree minimized, including such as was incurred by Adam's fall.

It was an intellectual adventure attended by much risk to investigate the unknown, especially when such searching meant using the eye aided with an optic tube to peer into the night skies to learn about God's

mysteries there. Milton in his "Paradise Lost" touches on this risk in a conversation between Adam and his mentor, Raphael. Adam asks about those bright specks dotting the blue dome of night, but Raphael admonishes him not to let his thoughts stray from his terrestrial affairs to matters which God designed to keep secret. However, if Adam would persist in such trespassing, well, perhaps God had put those curious specks there just to see what man would say about them and thus furnish God with some merriment over man's foolishness.

There were bright intellectuals scattered among the various countries of Europe and they travelled about in quest of any knowledge which they might acquire. Milton visited Galileo in his home city after the great disturber of the established order had become blind. Galileo's tormentors doubtless thought his blindness was divine punishment for his audaciousness in prying into the night skies. Galileo had his friends: Kepler the German astronomer; Tycho Brahe whom Kepler succeeded for a few years at the former's post; Copernicus whose theory of the universe displaced the old Ptolemaic system; and Giordano Bruno who was burned at the stake for refusing to disavow the Copernican theory.

When asked if he thought that modern astronomy had produced any intellectual overturning comparable to that which followed upon Galileo's day, Dr. Hubble answered in the affirmative and cited the discovery made with the Mount Wilson 100-inch Reflector that the Andromeda Nebula was a great galaxy of stars similar to our own Milky Way system in which our solar system lies. The Andromeda and myriads of other formerly supposed nebula formations have since been identified as enormous aggregations of stars. Away from metropolitan lights the Andromeda (so-called) Nebula may be seen with the unaided eye, during autumn nights, as though it were a tiny terrestrial cloud wisp. The Mount Wilson 100-inch Reflector has a possible range of 500 million light years into space. From its explorations of space it is learned that the island universes such as the Andromeda galaxy are more or less uniformly distributed. They are in various aspects or 'axial positions,' for they seem to be in rotation about some common center and they apparently have an orbital motion also not unlike the motions of our sun's family of planets. What further knowledge we shall derive with the aid of the Hale 200-inch Telescope no prophet pretends to say with authority. Having a range twice that of the Mount Wilson 100-inch Reflector, shall we discover that the system of galaxies constitutes a monstrous sphere? And, with the velocity of light at our command, shall we be able to start from a point and return again to it, just as now we can do on our mundane sphere?

As we work back to our objective let us imagine that we are building a great Temple to the Stars above or beyond that which electronics will build. We of the twentieth century should not flatter ourselves that the goal of astrophysics is about to be achieved. This indicates also that we should not look with disdain at our past. There is a considerable sub-

foundation which we shall not disturb but which is rich in "archaeological interest." Time will be thought of as the "fourth dimension" which will assist us in avoiding the sense of a musty past.

Undoubtedly the workman who contributed most to building our Temple to the Stars during the first half of our twentieth century was Dr. George Ellery Hale. Dr. Hale would decline any recognition that excluded others who worked with him. Yet history has a way, not unlike mountain formation, of creating eventually an uneveness that leaves some eminence towering above those that form its environment. Hale eventually will stand among those other outstanding builders of our Star Temple: Herschel, Fraunhofer, Dolland and Roemer, Huygens, Newton, Galileo, and Tycho Brahe, the Danish Instrument maker, who marks almost a cleavage between that archaeological past indicated and our modern era. It should be observed that no nation is exclusively eminent in its contributions to our Temple.

Astronomy used to be characterized by celestial mechanics and uninteresting mathematics. This from the layman's viewpoint. With Dr. Hale, astronomy was superseded by astrophysics, a term representing astronomy, physics, and chemistry. The photographic plate or film and the spectrograph are the two indispensable accessories of the modern telescope. The origins of these accessories are found part way down in our Star Temple. The photographic emulsion is one of the few things having no historic kinship with astronomy prior to the telescope. However it was not long after Daguerre and Niepce of France, after years of trial and error, in about 1840 succeeded so far in their art that the American, Dr. Draper, made the first successful attempt to photograph a celestial object—the moon. Harvard Observatory now has in its custody some of Dr. Draper's astronomical instruments and a large collection of his celestial photographs.

Photography and the spectrograph work together for best results. The human eye tires and is incapable of prolonged visual effort. The photographic plate registers, both ordinary celestial photographs, or, with the spectrograph, a band of different color values that tell what the chemical properties or elements of the object photographed are. The astrophysicist can study this spectrogram, as it is called, at his leisure in his laboratory. By this means also the astrophysicist ultimately may arrive at some idea of the axial and orbital motions of the celestial objects which he examines.

Spectroscopic science begins properly in 1817 with a brilliant young German, Joseph Fraunhofer. Mathematician, astronomer, optician, Fraunhofer died in 1817 when he was only 39 years old. Fraunhofer had the benefit of the earlier experiments of others like Wollaston and Newton in analyzing light. Almost everybody is familiar with prismatic colors such as Newton first produced with the use of a glass prism, which accounts for the term "prismatic colors." Fraunhofer's contribution to spectroscopy was in conceiving and then verifying by experiment

the use of a very narrow slit interposed in a beam of white light in producing a spectrum. The slit is a vital part of a spectrograph—two slits with a spectrohelioscope when a color spectrum is to be seen. Fraunhofer made a second experiment, this one called a grating made of fine piano wire wound over two fine-pitch screws firmly held apart to provide tension of the wire. With this crude device Fraunhofer produced a spectrum when held in white light. This led the noted American physicist, Rowland, to devise a ruling engine that uses a V-pointed diamond and "scratching" from 15,000 to as many as 40,000 lines per inch, usually on glass that is optically flat. The surface of such a grating presents a satiny appearance to the eye. Fraunhofer's name is perpetuated in astrophysical science by being used to designate those dark lines across the spectrum which he was the first to interpret understandingly, as due to interferences of elements or to temperature differences of those elements. Great strides have been made since his day in spectroscopy, and it is a most complex science as the following incident reveals.

McClure's Magazine for May, 1899, published an article about the elements hydrogen and nebulium. In a brochure written by Dr. Hale "The New Heavens" published in 1920, he refers to nebulium as a brilliant discovery which would stimulate the hope of more important achievements by the new 100-inch Reflector just then getting well organized for astrophysical work. About a dozen years later Dr. Ira S. Bowen, now director of the combined astrophysical institutions, disclosed that "nebulium" was the element oxygen a little "camouflaged" by the presence of another element. Spectroscopy is indeed a complex subject. Yet, as this incident reveals, in the hands of an expert much of its complexity sooner or later is unravelled, due to the fact that in the heated or incandescent state each element gives its characteristic color.

With the increasing size of the telescope an equatorial mounting is essential for accurate following of any celestial object. Again we are indebted to Fraunhofer, who conceived and made the first equatorial mounting. Then someone thought of applying a clock to drive it automatically. Clocks are a subject not confined to the astronomical telescope but which will richly compensate one's efforts to learn about them from water clocks or clepsydras to invisibly-driven electric time keepers.

No competitor to Fraunhofer's skill as an optician appears until the American portrait painter adventured upon the art. Now the astronomical world knows of the fame of Alvan Clark & Son of Cambridgeport, Mass., renowned lens-makers for telescopes. Then there later joined this firm from Sweden Mr. C. A. R. Lundin who with his son carried to greater fame the original firm. The son completed a 13-inch triplet objective which had been started by an amateur who also won wide recognition as an expert lens-maker, the Reverend Joel Hastings Metcalf, a Unitarian clergyman who held several pastorates around Boston.

Mass. It was this triplet objective, acquired by the late Percival Lowell, which was used in photographing the skies that resulted in spotting the planet Pluto by an amateur, Clyde Tombaugh. Finally, that machine-shop foreman, or rather millwright, "Uncle" John A. Brashear of Pittsburgh, Pa. Self-taught, his skill in optics brought fame to him from both his native land and from many European countries. Uncle John's greatness was enhanced by his profound humility. On the crypt at the base of the large telescope of the Allegheny Observatory, the burial place of Mr. and Mrs. Brashear, are inscribed these words supplied by Mr. Brashear: "We have Loved the Stars too Fondly to be Fearful of the Night."

Modern observational astronomy begins properly with Sir Frederick William Herschel. The story of his life and of that of his sister, Caroline, and of his son, Sir John, is an epic extraordinary. Son of a Hanoverian band musician, not of robust military fibre, his father managed to get him transferred to England where he eventually became a British citizen. He was born on November 15, 1738, in Germany. He followed the career of a musician and became noted as a director of choral and of instrumental music. Had he not been obsessed with astronomy Herschel might have attained in no small degree the renown of a Toscanini. The music of the celestial spheres had a stronger appeal to him with the result that he attained a permanent and lasting renown as both an expert craftsman and astronomer. All Europe including England was engaged in the throes of continental and colonial wars, but young Herschel hewed strictly to the line of astronomy, which meant that he had to make his own telescopes, all of which were reflectors. He made more than a hundred mirrors, from one or two inches in size up to his greatest reflector, four feet in diameter and having a focal length of forty feet. He had the unstinted cooperation of his sister Caroline, and of his son John as soon as he was old enough to lend a hand.

Compared with present-day instruments Herschel's telescopes were crudely mounted and depended mainly on hand controls. This only accentuates the skill of Herschel in relation to his accomplishments in observational astronomy. He scrutinized the night skies at every opportunity. It was with his six-inch reflector having a focal length of seven feet that he discovered the planet Uranus, the first planet found by chance visual observing. That was in 1781 when King George was agreeing to the Independence of what became the United States. Ere long other astronomers perceived unaccountable perturbations in Uranus' orbit and a prize was offered to the mathematician who would prove the existence of still another planet that caused those perturbations. Unknown to each other, John C. Adams, an Englishman, and U. J. J. Le Verrier, a Frenchman, expert mathematicians both, determined the probable position of such a planet. Adams' youthfulness did not inspire confidence in his superiors who pigeonholed his data. Le

Verrier's data were sent to the Berlin observatory. The astronomer there located the planet, which was subsequently named Neptune. It was first seen the 23rd of September 1846. The young Adams very soon came into prominence in his native country, for his results, arrived at prior to Le Verrier's, were too near the facts to go unrecognized.

Our sun with its family of nine planets and numerous lesser objects is travelling at more than eleven miles a second toward the constellation Hercules, or possibly nearer to the first magnitude star Vega in the constellation Lyra. Both constellations appear not far apart in the line of sight and may be seen during our summer evenings. Herschel first apprehended this motion simply by noting the apparent concentration of stars in that field and the disparity in the opposite direction. This has since been verified spectroscopically and this goal of our solar system is called the Apex of the Sun's Way. Even with this velocity-motion among the stars, our astronomer-mathematicians can predict the hour and the minute, place, and duration of a solar eclipse, and, barring clouds, those who can get there may witness a phenomenon that mystified the ancients. The distance light travels in a year has become the astronomer's yard-stick, and he combines these yard-sticks into a unit which he calls a parsec for stating immense stellar distances. But we go back to the year 1640 to the Dutch astronomer, Roemer, as the first to announce approximately the velocity of light. Before him such a question had not engaged the mind of man. Roemer was observing the time interval of eclipse of some of Jupiter's satellites. It may have been accidental, but he chanced to observe once when the earth was on the opposite side of the sun from Jupiter, and again when earth and Jupiter were each on the same side. There was an appreciable discrepancy in time which he noted and after a little calculation Roemer decided that light travelled about 186,000 miles per second. For a non-precision method that was a remarkably good approximation to the currently accepted figure.

Astronomy and the instruments for its study present a heterogenous picture before Herschel's time. Sir Isaac Newton, to whom science owes so much, concluded without sufficient thought on his part that it would not be practical to make a large telescope of the refractor type owing to the problem of overcoming chromatism. Any lens having a curved face by so much will produce colors, and the sharper the curve the greater will be the chromatic result. Thus Newton adopted the mirror or "reflector" type for his telescope design. During the several decades immediately following Newton's time, refractor telescopes were made, some with two hundred feet or more of focal length. The extraordinary length was to avoid too sharp a radius to the lens, otherwise chromatism vitiated the image. Every lens becomes to a certain extent a prism and thus white light is proportionately broken into separate colors. Those long telescopes required a small army to operate if the astronomer was to do any observing. Half a century after Newton

two of his fellow Englishmen, Hall and Dolland, about 1750, conceived that by combining two kinds of glass with suitable refractive qualities, chromatism might be much reduced if not altogether eliminated. Partial success resulted by this scheme, enough so that by late in the 19th century we had the Lick and the Yerkes refracting telescopes. Except for the practical difficulties in producing larger discs of crown and of flint glass, refractors might still be competing successfully with the reflectors. Both types use objectives, but the refractor bends the light rays, whereas the reflector reflects them. Each objective receives light in parallel rays and then conducts them in a cone to the optical train arranged for their reception, ultimately to the photographic plate or to the spectrograph.

Tycho Brahe, the celebrated Danish astronomer and instrument designer and maker, may with consistency be called the greatest of those pre-telescopic astronomers. Brahe links the telescopic era with his own by the fact that he accepted Copernicus' theory of the solar system, and that the first celebrated astronomer of the new era, Johann Kepler, took over much of Brahe's accumulated material and also served after Brahe's death in that official capacity in which Brahe had served for several years. Galileo was a close friend of these key men in those critical days. The answer to the query why the Dutch spectacle makers did not themselves seize upon the opportunity within their grasp, which Galileo recognized, must be ascribed to that difference between human beings so familiar in all human history. The telescope is accepted as a chance discovery made by one or two Dutch spectacle makers sometime between 1590 and 1609. The earliest claimant was Zacharias Jansen, and the other was Jan Lippershey. At first seeking a patent right to the discovery, this was not granted since it was difficult to determine who was the first to discover the fact that by holding a pair of spectacle lenses tandem before the eye the object viewed appeared closer than to the unaided eye.

Spectacles had been made for approximately five hundred years prior to Galileo's day. Only recently have writers on astronomical subjects given attention to the influence exerted by the noted Arab physicist, Alhazen, on the art of lens making. Alhazen is the Latinized form of his Arabic name—Abu Ali al Haitham. He was born in Basra, Turkey, about 965, and died in Cairo, Egypt, about 1038. In his monumental "History of Science" Sarton states: "Alhazen was the greatest Muslim physicist of all time. Whether it be in England or in far away Persia, all drank from the same fountain." Alhazen was an astronomer, mathematician, physician, and translator of numerous ancient authors such as Aristotle, Euclid, Ptolemy, and the noted physician Galen. This he did in addition to his own research and writing his personal manuscripts. Alhazen was an indefatigable worker. Sarton's estimate is confirmed by the voluminous material about him to be found in the great

libraries of Paris, the Bodlean library of Oxford, and significantly, Leyden, Holland, birth-place of the telescope.

"Come with me—I have something to show you."

It was Dr. Bowen, Director of the Mount Wilson and the Palomar Astrophysical Observatories. He indicated a chair for me to occupy while he drew from a steel cabinet a large book which he handed to me saying, "Look at that."

It was a plain, shiny, pig-skin bound volume about nine by thirteen inches and about one and a half inches thick. It had no exterior markings. Opening the book I found it to be a Latin translation in two divisions. The first was of Alhazen's *Kitab al Manazir*—treatise on optics. The second was of the Polish physicist Vitellio which was based largely on the work of Alhazen, originally written in 1272. The volume which I held in my hands was the work of Frederico Rinsnero of Basle, Switzerland, and printed in 1572. Printnig and book binding were then scarcely a hundred years old, yet this volume measures up to some so-called *de lux* editions. Elegant book-plate engravings head each of the two divisions. Geometrical figures appear all through the work, in some cases two or more on a page. These are of a quality not to shame modern engineers, and the engraver's art as exhibited by these figures is of a rare quality.

Not in any sense a zealous worshipper, I must own to a feeling of profound respect for those founders of modern optics whose work lies at the base of our Temple to the Stars.

"Yet I doubt not thro' the ages one increasing purpose runs,
And the thoughts of men are widened with the process of the suns."

(Tennyson's "Locksley Hall.")

1114 E. Orange Grove Ave., Pasadena 6, California.

Contributions of the Meteoritical Society

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

The La Lande, New Mexico, Chondrite (ECN = +1041,344)*

CARL W. BECK,† RALPH G. STEVENSON, JR.,‡ *and* LINCOLN LAPAZ§
University of New Mexico, Albuquerque

ABSTRACT

In this paper are given details concerning a chondritic meteorite found in 1933 near the La Lande post office in De Baca County, New Mexico. Macroscopic and microscopic mineralogical examinations and chemical analyses are given. The meteorite is composed chiefly of olivine and enstatite (variety, hypersthene), lesser amounts of a dispersed metallic phase, and small percentages of enstatite-clinoenstatite intergrowths and secondary hematite. On the basis of this investigation, the La Lande meteorite is classified as a hypersthene-olivine chondrite (Chy). Evidence is presented to indicate that the La Lande aerolite may not be a distinct fall, but may be simply a member of the widely scattered Melrose, Curry County, New Mexico, shower. Three (3) figures and 2 tables are given.

INTRODUCTION

The Joe R. Heaston Collection of New Mexican Meteorites (purchased from H. H. Nininger, now of the American Meteorite Museum near Winslow, Arizona) at the University of New Mexico contains 2 aerolitic specimens designated as follows:

15. La Lande, De Baca County, 1933, stone, 77 pounds (single mass), Specimen 464.50, weight 3¾ pounds [= 1.700 kg.].
16. Melrose, Curry County, 1933, gold-bearing stone, 84 pounds (several masses), Specimen 174.92, weight 7½ pounds.

Essentially the same information regarding these 2 meteorites is given by Northrop.[1] Specimen 464.50, which also carries the registration number IOM-6 in the collection of the Institute of Meteoritics, was studied in this report.

The foregoing facts represent essentially all of the information that has previously been available on the La Lande meteorite (ECN = + 1041,344). Mention of it was made by Nininger[2] in his paper on the nearby Melrose, Curry County, New Mexico, meteorite (ECN = +

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†Department of Geology and Research Associate, Institute of Meteoritics.

‡Department of Geology.

§Department of Mathematics & Astronomy and Director, Institute of Meteoritics.

1036,344; cl. = chondrite, C). Because of the similarity of the La Lande and Melrose meteorites, the question naturally arises as to whether or not they are distinct, or are simply widely separated members of the same meteoritic shower. If the latter possibility can be proved to be a fact, then the name *Melrose* should probably take precedence for both, by reason of priority. The one distinct difference should be the presence of gold in Melrose, called "the only gold-bearing meteorite in America."[3] Recent chemical analyses in this laboratory of 4 representative fragments of the Melrose meteorite, in which the Purple of Cassius and phenylhydrazine-acetate methods of testing for gold were utilized, have failed to show any gold content. Analyses of La Lande also have failed to indicate any gold.

Macroscopic Examination

In shape, the 1,700-kg. La Lande specimen studied in this report closely resembles a crude oblique pyramid with a rounded apex (Fig. 1B). Approximately half of the lateral area is occupied by a gently rounded surface; the remaining half is divided between 2 smaller faces containing angular pits and projections. These latter 2 faces meet at an angle equal roughly to 65°. The entire basal area is composed of the flat surface left by the saw when the specimen was cut from the larger mass (Fig. 1A).

The area of the base is approximately 100 square cm. The altitude of the pyramid is 11 cm. The slant-height of the large rounded surface is slightly under 18 cm.

The appearance of the large rounded surface differs somewhat from that of the more angular surfaces, and the basal face, being an interior face, naturally differs from all the others, inasmuch as they have been exposed to conditions inducing alteration, whereas the base has been protected.

The large rounded surface is reddish-brown; it has the general appearance of an unsorted, ferruginous sandstone and is covered with fine pits and an occasional large one. A rather granular appearance with some observable chondrules is presented entirely over this surface, which is apparently a portion of the original surface that was most exposed to the rigors of high-velocity flight thru the outer atmosphere.

The other exterior surfaces exhibit a mottled, red-brown color similar to that of the large surface, but they have a much less eroded appearance. No chondrules were noted. The difference in surface texture between the gently rounded surface and the more angular ones may be due to either one of two causes. It may be a result of the shattering, or the explosion, of a larger mass in the atmosphere. This would offer fresh surfaces to erosion but would not halt erosion on the older surfaces. The new surfaces would thus suffer much less alteration than the older ones. A similar alternative lies in the possibility of explosion or shattering on contact with the ground. This would leave fresh sur-

FIG. 1
THE LA LANDE METEORITE: A. SAWED SURFACE SHOWING DISPERSED METALLIC PHASE; B. EXTERIOR SURFACE

faces exposed to weathering forces and would produce an alteration differing from that on the pre-shattering exterior surfaces.

The interior of the stone, as exposed on the cut, is deep brownish-green, with scattered metallic nodules ranging from microscopic size to 6 mm. in diameter. A few of the larger metallic nodules show troilite surrounded by kamacite (Fig. 1A). Individual minerals are not generally distinguishable. An iron-oxide stain is seen to cause the reddish color of the exterior surfaces. This color extends only a very slight distance into the body of the stone; it is generally vanishingly small as viewed in cross-section, being at most only a few tenths of a millimeter thick. This iron oxide follows a few cracks into the interior of the stone to the full depth of the cracks. Within the oxidized portion of one small crack near the surface of the stone there appears to be a local concentration of extremely fine metallic particles. This is thought to be a "residual concentration," and indicates a profusion of fine metallic particles evenly distributed thruout the body of the stone.

No fusion rind is visible on macroscopic examination. Because it is not known how long this specimen had lain in the ground before its discovery in 1933, it seems entirely possible that such a feature may have weathered away. There is, however, no evident reason for postulating that such is the case.

Microscopic Examination

Thin-Section Analysis.—Thin-section analysis of the La Lande aerolite shows it to be composed of olivine and enstatite (variety, hypersthene), with a small percentage of enstatite-clinoenstatite intergrowths, secondary hematite, and opaque metallic grains. Under plane light, the minerals are seen to be strongly stained by an iron oxide, hematite. Because olivine is readily altered to hematite, it is believed that it, rather than the metallic phase or external causes, is the source of most of the

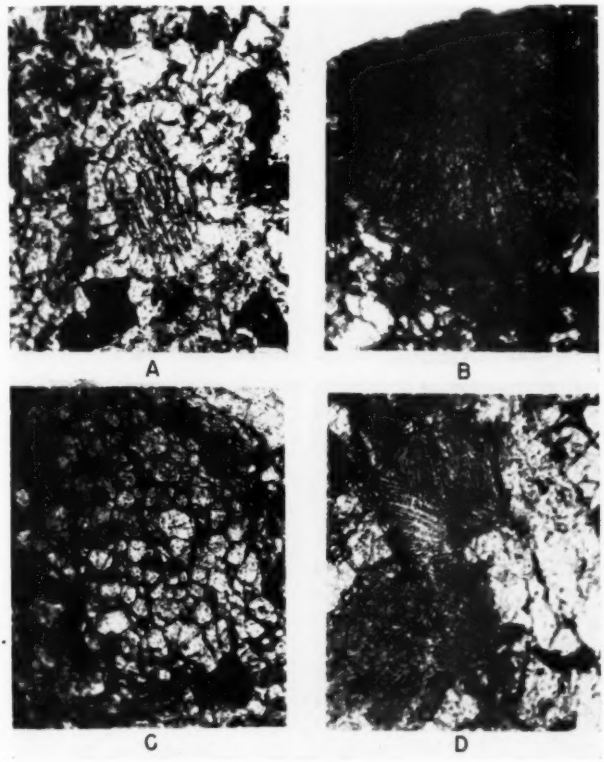

Fig. 2

Typical La Lande Chondrules (See text for Explanation.) × 100.

iron oxide. The alteration of hypersthene to iron oxide along cleavage planes also is evident.

Examination of the thin-section under crossed nicols shows that the forenamed 2 minerals are present in the proportions of about 40% olivine and 60% hypersthene. The grains of both minerals are generally fragmental, altho some subhedral and euhedral olivine grains were noted. At one place, several olivine grains appear to be set in a matrix of randomly oriented, fibrous hypersthene.

Many distinct chondrules, comprizing approximately 15% of the section, were noted. These are composed generally of globular aggregations of mineral particles, and may consist of one or several minerals. There is a wide range of internal structure. The majority of the chondrules noted in this section are composed primarily of small olivine fragments, generally with a small amount of hypersthene, and are mostly imperfectly developed (Fig. 2C). Examples of well-formed chondrules were noted, however. These are composed usually of a fibrous intergrowth of hypersthene and clinohypersthene, with a well-displayed radiate structure (Figs. 2B and 2D). The different character of the constituent minerals is shown by the inclined extinction of some of the radiating fibers as contrasted with the parallel extinction of normal hypersthene displayed by the rest of the fibers. A barred chondrule is illustrated in Fig. 2A. According to Merrill,[4] the barred forms are limited mainly, if not wholly, to monosomatic forms composed of olivine. The chondrule illustrated is, however, composed of hypersthene with alternating bars of iron oxide.

Oil-Immersion Analysis.—Altho the oil-immersion analysis was rendered more difficult than usual by the masking effect of the abundant iron oxide, it was possible to obtain detailed optical constants for the non-opaque minerals.

The olivine gave the following optical constants: $\alpha = 1.683$, $\beta = 1.702$, $\gamma = 1.721$; optical character, negative; axial angle, 85°; dispersion, $r < v$, weak; optical orientation, $X = b$, $Y = c$, $Z = a$; axial plane, {001}. These constants indicate an olivine with a molecular percentage of Fe_2SiO_4 equal to 24.2, and a specific gravity of 3.65. The corresponding percentage by weight of FeO is 22, and of MgO, 39.

The hypersthene gave the following optical constants: $\alpha = 1.704$, $\beta = 1.713$, $\gamma = 1.718$; optical character, negative; axial angle, 70°; dispersion, $r < v$, weak; optical orientation, $X = a$, $Y = b$, $Z = c$; axial plane, {010}. These constants indicate hypersthene with a molecular percentage of $FeSiO_3$ equal to 32.5, and a specific gravity of 3.45. The corresponding percentage by weight of FeO is 21, and of MgO, 24. The usually diagnostic pyroxenic prismatic cleavage {110} was seldom evident. The lower interference colors of the hypersthene provided the only easily discernible, distinguishing feature for differentiation between olivine and hypersthene under crossed nicols. No pleochroism, so characteristic of hypersthene, was noted, altho this may

well have been present but masked by the omnipresent iron-oxide stain. Some of the hypersthene grains exhibited an undulatory extinction. This is probably an indication that these grains are under some strain.

Some shards of glass were noted in the oil-immersion analysis. The refractive index of this glass is 1.551. Some evidence of strain in the glass is the lack of complete extinction under crossed nicols. Because the glass could not be distinguished in thin-section, the relationship it bears to the other minerals of the meteorite could not be ascertained. According to Farrington,[5] meteoritic glass "abounds as inclusions and intergrowths in chrysolite [olivine], taking, in this association, a great variety of forms." This association is not, of course, universal. The occurrence of glass is taken as an indication generally of "a rapid crystallization or cooling of the meteoritic substance."[6]

FIG. 3

THE LA LANDE METEORITE: KAMACITE, GRAY; TAENITE, WHITE; AND PLESSITE, BLACK, SURROUNDING WHITE TAENITE. NITAL, 15 SEC. × 50:

Polished-Section Analysis.—A polished section of the La Lande meteorite was prepared and studied to obtain information relating to the metallic phase of the specimen. The section was etched with nital for 15 seconds to bring out the relationships of the components. A photomicrograph of a portion of this section is shown in Fig. 3 and demonstrates the relationship of kamacite, taenite, and plessite. The majority of the metallic nodules in the section consist entirely of kamacite. A very few show taenite and even fewer exhibit plessite. No troilite was noted in the section, but it can be seen occasionally, inclosed in kamacite, on macroscopic examination of the sawed surface of the large specimen (Fig. 1A). The metallic nodules can be seen to have a random distribution thruout the specimen.

Chemical Analyses

Quantitative chemical analyses of the metallic phase, the non-metallic phase, and the undifferentiated entirety of the meteorite were made and are shown in Tables 1 and 2. Molecular proportions of the metallic phase and a normative calculation of the non-metallic phase are shown in Table 2. It will be noted that the mineral diopside is in the normative calculation, altho that mineral was not found in the thin-section analysis; it is entirely a normative mineral, used to help explain the chemical analysis. Of course it is possible that diopside is present in the meteorite and was overlooked, but it is more probable that the Al_2O_3, CaO, K_2O, Na_2O, and MnO are present as isomorphic substitutes in the olivine and the hypersthene. These analyses are in agreement with the microscopic studies.

Table 1

Chemical Analysis of the La Lande Chondrite

	Percent
Silica, SiO_2	28.33%
Iron oxide, Fe_2O_3	31.20
Aluminum oxide, Al_2O_3	6.05
Calcium oxide, CaO	2.53
Magnesium oxide, MgO	24.81
Potassium oxide, K_2O	0.21
Sodium oxide, Na_2O	1.81
Nickel, Ni	1.42
Cobalt, Co	0.62
Manganese, Mn	1.01
Sulfur, S	1.21
Chlorine, Cl	1.23
Titanium, Ti	0.00
Phosphorus, P	0.45
Carbon, C	none detected
Total	100.88%

TABLE 2

CHEMICAL ANALYSES OF THE METALLIC AND NON-METALLIC PHASES OF THE LA LANDE CHONDRITE

Metallic Phase	
Fe	88.08%
Ni	7.89
Co	0.64
P	0.47
S	1.22
Cl	1.34
C	0.00
Total	99.64%

Molecular Proportion: $\frac{Fe}{Ni} = 11.73$

Molecular Proportion: $\frac{Fe}{Ni + Co} = 10.86$

Non-Metallic Phase	
SiO_2	32.01%
Fe_2O_3	27.81
Al_2O_3	6.34
CaO	2.86
MgO	28.04
K_2O	0.20
Na_2O	2.05
MnO	1.14
TiO_2	0.00
C	0.00
Total	100.45%

Normative Calculation	
Hypersthene	42.17%
Olivine	41.20
Diopside	9.86
Hematite	6.77

Metallic Phase .....17.98% by weight
Non-Metallic Phase .....82.02% by weight

SUMMARY AND CONCLUSIONS

On the basis of the foregoing studies, we classify the La Lande meteorite as a hypersthene-olivine chondrite (Chy), following the Leonard classification.[7] The strong alteration of olivine to iron oxide is taken to indicate that the stone fell a considerable time prior to its discovery in 1933. In accordance with the "meteorite-planet" hypothesis originated in 1850 by Boisse, advanced independently by Farrington in 1901, and recently strongly supported by Brown[8] from thermodynamic considerations, this stone would have come from the exterior mantle of the hypothetical meteorite-planet. This conclusion is thought to be true because the meteorite-planet is supposed to have had a core of nickel-iron with a gradation to an exterior mantle of enstatite and olivine; therefore, the less the metallic phase present, the farther from the center of the planet did the meteorite have its origin.

It has been recognized at the University of New Mexico that the La Lande and Melrose meteorites are strikingly similar. Specimens of both stones are seen to possess an essentially identical overall color on cut surfaces—a deep brownish-green. The mineral composition of the non-metallic phase of both stones shows great similarity. The amount and the distribution of the metallic phase of both specimens, as shown on cut surfaces, reveal close similarity. Both meteorites exhibit the relatively unusual feature of macroscopically observable troilite nodules surrounded by kamacite. The only observable difference between the

two meteorites is a difference in surface coloration, which might easily have arisen from dissimilar environmental circumstances after arrival on the Earth.

This paper represents part of a careful study that is being carried out by us, of the possibility that these two stones belong to the same fall. On the basis of the complete La Lande study and the studies already made on the Melrose aerolite, it is believed, at the present time, that La Lande is not a distinct fall, but is simply a member of the widely scattered Melrose shower. Since, according to Leonard,[9] the longitude of the Melrose find, to the nearest tenth of a degree, is + 103°.6, whereas that of the post office at La Lande, New Mexico, near which the La Lande specimen was found, is approximately + 104°.1, it follows that the linear extent of the Melrose strewn field is of the order of 28 miles, and hence that this fall is the most extensive of all the recognized meteoritic showers.

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The Real and Apparent Stellar Magnitudes of Telescopic Meteors

C. C. Wylie

Department of Mathematics & Astronomy, State University of Iowa, Iowa City

Abstract

Six (6) dual observations of meteors, made with the naked eye and with a telescope or binoculars, are discussed. It is found that one (1) was a "point" meteor. Two (2) were "line" meteors seen with the telescope or binoculars before being noticed with the naked eye and at below-the-naked-eye magnitude. Three (3) were "line" meteors, for which the binocular and the naked-eye observers recorded essentially the same real magnitudes.

The relation between the real and apparent magnitudes of meteors observed in a telescope is a matter of importance in obtaining the daily numbers of telescopic meteors of various magnitudes. These numbers, in turn, are important in calculating the total amount of meteoritic material falling onto the Earth each day. Formulas for calculating the

real magnitudes of meteors from their apparent magnitudes as seen in a telescope or binoculars were published by me in *Contr. State Univ. Iowa Obs.*, **1**, 270-3, and in *P. A.*, **45**, 556-9, 1937.

There are two ways of recording the apparent magnitude of meteors as seen in a telescope. One is to record the magnitude of the meteor as seen in the telescope as that of a star of the same apparent magnitude as seen with the naked eye. This procedure makes the faintest magnitudes ordinarily seen with any instrument about + 5. The second, and presumably more accurate, way is to record the magnitude of a meteor as that of a star of the same apparent magnitude as seen thru the telescope. In this way, apparent magnitudes of + 7 and + 8 would be recorded occasionally with binoculars, and fainter magnitudes with a telescope.

A fast-moving meteor is seen as a line, and if its magnitude is recorded as that of a star of the same apparent brightness seen in the telescope or binoculars, the meteor is in reality brighter by $\Delta m = 2.5 \log M$, where m is the magnitude of the star and M is the magnification used. The magnitude of a slowly-moving meteor, which is seen as a point of light, is the same as the magnitude of a star of the same apparent brightness as seen in the telescope or binoculars.

Let us now apply these formulas to simultaneous naked-eye and telescopic observations of meteors where the magnification used in the telescope or field glasses is given. The observations discussed here were all published before the formulas mentioned in the preceding paragraph were published, and the articles indicate that the observers did not know the relation between the real magnitude and the apparent telescopic magnitude. It is safe to assume that the recorded magnitudes are free from any bias. The first observation used was made by Monnig and Logan, and is reported by Charles P. Olivier in *P. A.*, **39**, 606, 1931. The remaining 5 were made by Williams, Knabe, and Brinegar, and are reported by J. D. Williams in *P. A.*, **45**, 498-9, 1937.

The following table gives, in the first column, the author; in the second, the magnification; in the third, the naked-eye magnitude; in the fourth, the apparent telescopic magnitude; in the fifth, Δm, computed from the foregoing formula; and, in the last, the corrected telescopic magnitude.

TABLE 1

Author	*Magnification*	*Naked-Eye Magnitude*	*Apparent Telescopic Magnitude*	Δm	*Real Telescopic Magnitude*
Olivier	130	1	9	5.3	3.7
Williams (1)	1.3	4	4	0.3	3.7
Williams (2)	7	1.5	7.5	2.1	5.4
Williams (3)	7	4.5	4.5	2.1	(4.5)
Williams (4)	7	5	7	2.1	4.9
Williams (5)	7	3	5	2.1	2.9

For the Olivier report and Williams (2), the corrected, or real, telescopic magnitude is definitely fainter than the naked-eye magnitude,

thus indicating that the telescopic observer picked up the meteor while it was increasing in brightness. The unobserved gap is given as 20° for the Olivier report, and was not recorded for Williams (2).

For Williams (3), the binocular observer recorded a "slow-moving, 4.5-magnitude meteor." Presumably this was seen as a point of light, and the Δm should not be applied. On that assumption, the binocular and naked-eye magnitudes are in perfect agreement.

For Williams (1), the gap between the binocular and naked-eye observations was 10°, and the meteor made a "long flight." For Williams (4), the gap was presumably small, since it is not mentioned. For Williams (5), the gap is given as 2°. For all 3 of these meteors, the assumption of a line appearance and the application of Δm make the differences between the naked-eye and the real telescopic magnitudes 0.3, 0.1, and 0.1, respectively. Since the estimates were made to only the nearest half-magnitude, the agreement is excellent, thus indicating that, for these meteors, the binocular and the naked-eye observers saw the meteors at the same brightness.

Perhaps it would be well to add here a request that meteor observers make more telescopic counts, being careful to use relatively low-power and wide-field instruments, and recording the power, aperture, and width of field of the instrument used and the apparent magnitude of each meteor observed. Simultaneous naked-eye and telescopic observations, similar to those discussed in this paper, would be both interesting and valuable.

1950 December 21

A Method for Permanently Marking the Exact Locations of Meteorite Discoveries

Russell A. Morley

399 North 18th Street, Salem, Oregon

Abstract

A method for permanently marking the exact location of each meteorite discovered, and a plan for the construction and erection of a convenient type of permanent marker, similar to those in use by the United States Coast and Geodetic Survey, are described.

Permanently marking the exact location of each meteorite discovered has long been neglected, and, in many cases, has resulted in serious and widespread confusion, especially in the early days of meteoritics, when accurate maps were non-existent or were at best limited in their availability. Little if any importance was attached to preserving the record of the precise locations of discovered meteorites. The Red River, Texas, meteorite (ECN = + 952,321 : ; cl. = Om) is an extreme example of this unfortunate condition; and, to date, little has been done to correct it. Dr. Frederick C. Leonard's fine work on coördinate numbers con-

stituted a great step forward, but even that is necessarily subject to the limitations imposed by inaccurate determinations of longitude and latitude, which at best are rarely correct to the closest second of arc. Even this precision is not sufficient to locate the *exact* position, especially in difficult terrane, in which a few feet may make such work nearly if not quite impossible. Nature and man tend to destroy the earthly impression left by an extraterrestrial arrival soon after its removal from its place of fall! Combining the equatorial coördinate number (ECN) with a properly installed meteorite-monument marker would, however, provide a definite and final solution to the problem of exactly designating the original earthly location of a meteorite.

With the exception of the Canyon Diablo, Arizona, meteorites (ECN = + 1110,350; cl. = Ogg) and a few other crater-producing falls, meteorites have left few if any permanently recognizable features after striking the Earth. Erosion and man have combined to obliterate the original impressions left by large meteorites, such as the Willamette, Oregon, siderite (ECN = + 1227,454; cl. = Om), in a very short time. After the span of 48 years since the discovery of the Willamette meteorite by Mr. Ellis Hughes, in 1902, and its subsequent removal, little lasting impression remains except small fragments of the oxidized crust, which are still to be found lying in its crater. It would be impossible without previous knowledge to distinguish the crater made by that meteorite from the many similar depressions left by decayed tree-stumps in the vicinity.

In the case of multiple falls or showers, it would not be practicable to mark each individual meteorite recovered; only the largest and the most important individuals would need to be marked.

In the accompanying sketches (Figs. 1, 2, & 3), I give the plan of

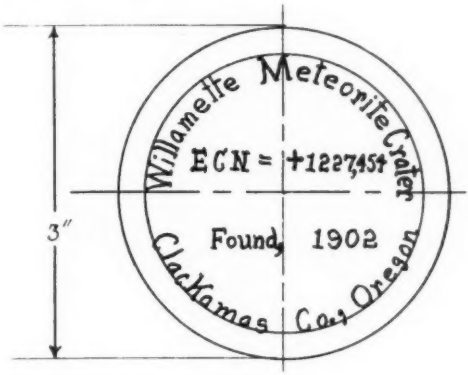

Fig. 1
Meteorite-Monument Plan:
Brass Marker-Spool Face
Diameter = 3 inches

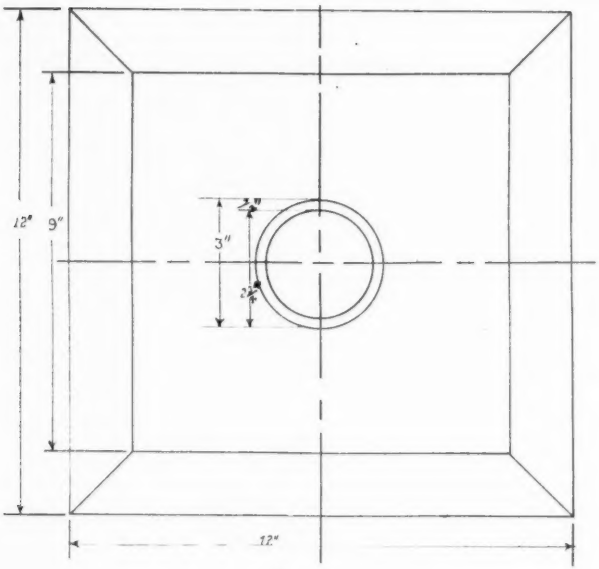

FIG. 2
METEORITE-MONUMENT PLAN:
CONCRETE MARKER BASE
12 inches Square

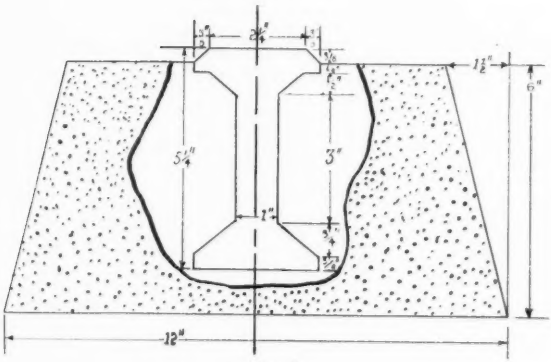

FIG. 3
METEORITE-MONUMENT PLAN:
SIDE VIEW OF CONCRETE BASE:
"CUTAWAY" TO SHOW MARKER-SPOOL DETAIL
12 × 6 inches

a monument marker that I believe would include all the desirable features and that would be both reasonably permanent and easy and eco-

nomical to construct. This kind of marker would be very similar to those in use by the United States Coast and Geodetic Survey, which have proved themselves, over many years, to be a most satisfactory type of permanent marker. The meteorite-monument marker would consist of 2 parts: (1) a brass or bronze marker-spool, with its circular top or exposed face 3 in. in diameter, imbedded in (2) a concrete block 12 in. square at its base, with its sides tapering to form a 9-in. square at its top; this block would have an overall height of 6 in. On the face of the marker-spool, inscribed by steel lettering-stamps, would appear the name, county, state, equatorial coördinate number (ECN), and date of fall or find of the meteorite, as shown in Figs. 1, 2, and 3, for the great Willamette iron.

A Note on the Lost Port Orford, Oregon, Meteorite

Lincoln LaPaz

Institute of Meteoritics, University of New Mexico, Albuquerque

Abstract and Introduction

In this note attention is called to several errors and omissions in an article on the lost Port Orford, Oregon, meteorite, published by J. Hugh Pruett in the October, 1950, issue (*C.M.S.*, **4**, 286-90; *P. A.*, **58**, 402-5, 1950).

In reading J. Hugh Pruett's paper, hereinafter referred to as *P*, on the lost Port Orford meteorite, the following errors and omissions were noted:

1. The weight of the specimen of Port Orford in the U. S. National Museum is not 28 gm., as stated in *P*. A letter to me from the U. S. National Museum, written under date of March 13, 1935, gives the weight of this piece as 25 gm., on the authority of W. F. Foshag. The same weight is given by E. P. Henderson in a letter written to me on December 3, 1941. When I pointed out the discrepancy between this weight and that given in *P*, Henderson very kindly made an exact determination of the weight of the Port Orford specimen in question, and, in a letter written me on November 30, 1950, stated that it weighs 24.15 gm. This specimen was obtained by exchange with the Boston Society of Natural History.

2. The two specimens of Port Orford in the Vienna and U. S. National Museum collections, respectively, are not the only known specimens of this pallasite, as stated in *P*. The meteorite collection in the Indian Museum in Calcutta also contains fragments of Port Orford, one of which, No. 1, weighs 0.19 gm. (*v.* G. T. Prior, *Catalogue of Meteorites*, p. 142, 1923, and A. L. Coulson, *Catalogue*, p. 178, 1940).

3. The year of the discovery of the Port Orford pallasite was certainly not 1859, as stated in *P*, since Evans found the mass in the course of the last war with the Rogue River Indians, and this war ended in the summer of 1856. Evans reached San Francisco on his way back to Washington on September 15, 1856, and there is evidence that he re-

mained in or near Washington, D. C., from the time of his return to that city until his death, except while absent on his ill-fated trip to Central America in 1860.

4. Evans died in Washington, D. C., not in 1860, as stated in *P*, but in 1861, on May 16, according to an obituary sketch prepared by his former field assistant, Dr. B. F. Shumard, and read at the meeting of the Academy of Science of St. Louis on August 19, 1861; but on April 13, 1861, according to his friend, Dr. C. T. Jackson, who was responsible for the identification of the Port Orford specimen submitted to him by Evans in 1859. Incidentally, Jackson was a resident of Boston, Massachusetts, not of New York City, as stated in *P*.

5. The location data that have been given for Port Orford are more confusing and self-contradictory than they are indicated to be in *P*. My interest in this lost meteorite was aroused by John E. Wolff, then Curator of Minerals at the Peabody Museum, when I was an instructor at Harvard University in 1921-22. At his suggestion, I made inquiries at the Boston Society of Natural History concerning this meteorite and its discovery and ascertained that the *original catalog entry* of the Boston Society relating to Port Orford stated that it was found "240 miles from Port Orford," not 40 miles, as given in *P* and elsewhere. Many other inconsistencies in accounts relating to the finding of the Port Orford meteorite were uncovered in conversations with Harold Sauers of Agate Beach, Otto Ismert of Pistol River, and, particularly, with the pioneer, George White, of Port Orford, Oregon, in the course of the investigations carried out in Curry County, Oregon, by an Ohio State University field party in the summer of 1934.

In view of the uniformly negative results attending all searches that have been made for the lost meteorite, I now share the view finally adopted by Wolff, *viz.*, that the main mass of the meteorite has suffered the fate forecast for it in the following interesting memorial sent to Congress by the Academy of Natural Sciences of Philadelphia, in 1860:

"To the Senate and House of Representatives of the United States of America, in Congress assembled:

"The undersigned, a committee appointed by the Academy of Natural Sciences of Philadelphia, for the purpose of aiding the efforts of Dr. J. Evans to procure the meteorite now lying near Port Orford, Oregon, respectfully present: That the discovery and preservation of meteorites is an object of great solicitude to scientific men, and that such specimens, besides the interest which attaches to them as the only objects we can reach foreign to the mass of our Earth, are considered as possessing great value in scientific collections; and understanding that the one observed by Dr. Evans is so situated that it can be transported to the coast for shipment at a comparatively small cost, they would respectfully urge the great importance of securing it as soon as practicable,

since, by the delay, it may become so covered with earth that the knowledge of its position may be lost.

"John L. LeConte
"Samuel Powel
"W. W. Rushenberger
"Isaac Lee, *President*
"Robt. Bridges, M. D., *1st Vice-President*
"John LeConte, *2nd Vice-President*
"Thos. Stewardson, *Corresponding Secretary*
"B. Howard Rand, M. D., *Recording Secretary*"

President of the Society: L. F. BRADY, 922½ Forest Avenue, Tempe, Arizona
Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

The Planets in March, 1951

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac.*

Sun. This month the sun's change of declination is the greatest: from 8 degrees south at the beginning to 4 degrees north of the equator at the end. The date of crossing the equator, called the vernal equinox, is March 21 at 4 A.M.

An annular eclipse on March 7 will be visible as partial from all except the northwestern third of the United States, beginning at about 4 P.M.

Moon. The phases of the moon will occur as follows:

New Moon	March	7	3 P.M.
First Quarter		15	12 noon
Full Moon		23	5 A.M.
Last Quarter		30	12 midnight

The moon will be nearest to the earth on March 27.

Evening and Morning Stars. Venus will shine in the early evening sky, and Saturn all night.

Mercury. Since it will pass superior conjunction on March 11, Mercury will be practically invisible this month.

Venus. This brightest planet will become still brighter and will remain above the horizon until after 8 P.M.

Mars. Although Mars will still be an hour east of the sun in the western evening sky, its second-magnitude faintness will make it difficult to spot without charts and instruments.

Jupiter. Its conjunction with the sun on March 11 will cause Jupiter to be practically invisible during this month.

Saturn. In contrast to Jupiter, Saturn, located in Virgo, will pass opposition to the sun on March 20, so that it will shine all night. To classical mythology

this special configuration might indicate a diametric separation of Power from Wisdom, with the latter virtue dominant.

Uranus. Uranus will be almost stationary, at about a degree north of μ Geminorum.

Neptune. Neptune will be moving northwestward, at less than a degree southeast of θ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.,
January 7, 1951.

Asteroid Notes

By HUGH S. RICE

The French monthly observers' bulletins known as *Documentation des Observateurs* was mentioned in these Notes in the issue of 1950 January. We have been receiving them regularly and note an improvement in form and arrangement. The latter is now more standardized. For instance, the 1951 January issue consists of a 4-page cover which encloses 4 printed fascicles or parts, each fascicle having 4 pages. Fascicle no. 1 gives general information and news on comets, meteors, and stars, together with magnitude-sequences and diagrams. No. 2 is devoted to minor planets, with remarks, an ephemeris, and diagrams of apparent paths of asteroids. These diagrams often have stellar sequences marked, so the observer can make a good estimate of the planet's magnitude. The diagrams are well drawn and are quite similar to those offered formerly in this department. No. 3 is given to notes on observation of comets and meteors, and includes a large chart of a comet path. No. 4 gives star charts with text. The subscription price of the "DOB" remains the same for surface mail, but the air-mail service is now marked "at cost price" instead of double the surface-mail fee. In the bulletins, considerable attention is given to the asteroids.

During this period there are no new bright asteroids, the brightest ones available being the following: (1) 129 ANTIGONE, of magnitude 9.9, comes to opposition February 28, and is found in Leo, between the triangle and the sickle. (2) 30 URANIA, of magnitude 10.5, comes to opposition March 15, and is found in western Virgo and southern Leo. (3) 52 EUROPA, of magnitude 10.0, comes to opposition March 28, and is found in western Virgo. The calculated positions of the asteroids follow.

ASTEROID EPHEMERIDES
0^h U.T. Equinox 1950

129 ANTIGONE

1951		α	δ
		h m	° ′
Feb.	13	10 51.7	+13 10
	23	10 44.6	+14 44
Mar.	5	10 36.8	+16 16
	15	10 29.1	+17 38
	25	10 22.3	+18 43
Apr.	4	10 17.2	+19 23

1951	30 URANIA α h m	δ ° ′	1951	52 EUROPA α h m	δ ° ′
Feb. 23	11 55.3	— 1 49	Mar. 5	12 40.9	+ 4 44
Mar. 5	11 46.8	— 1 6	15	12 34.9	+ 5 51
15	11 37.4	— 0 12	25	12 27.9	+ 6 55
25	11 28.0	+ 0 44	Apr. 4	12 20.7	+ 7 51
Apr. 4	11 19.7	+ 1 35	14	12 14.0	+ 8 35
14	11 13.4	+ 2 17	24	12 8.7	+ 9 3
24	11 10.2	+ 2 48	May 4	12 5.6	+ 9 11

Hayden Planetarium, American Museum of Natural History, New York,
1951 January 20.

Occultation Predictions for March, 1951

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1951	Star	Mag.	IMMERSION Greenwich C.T. h m	*a* m	*b* m	Angle E from N °	EMERSION Greenwich C.T. h m	*a* m	*b* m	Angle E from N °
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Mar. 9	62 Pisc	6.1	22 48.5	—0.7	—0.3	61	23 52.5	—0.3	—0.5	242
15	38 B.Auri	6.5	3 52.3	—0.2	—1.3	87	4 52.4	+0.3	—1.4	280
28	135 B.Scor	6.0	9 27.3	—1.9	—0.2	93	10 46.3	—1.7	—0.9	285
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′										
Mar. 9	62 Pisc	6.1	22 31.2	—1.2	+0.2	57	23 43.4	—0.8	0.0	236
9	δ Pisc	4.6	23 15.3	—0.6	+2.2	13	0 3.8	—0.9	—2.3	284
15	38 B.Auri	6.5	3 50.7	—0.4	—2.2	118	4 53.0	—0.6	—0.7	249
19	γ Canc	4.7	6 35.4	..	..	57	7 5.5	..	..	3
28	135 B.Scor	6.0	8 54.3	—1.4	+0.2	113	10 12.7	—2.0	0.0	277
OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +31° 0′										
Mar. 9	δ Pisc	4.6	22 55.3	—1.2	+1.2	41	0 7.7	—1.0	—0.3	251
18	*c* Gemi	5.4	1 23.7	—2.7	+0.7	87	2 53.6	—2.0	—2.3	312
19	γ Canc	4.7	6 29.7	—1.5	—1.3	99	7 33.7	0.0	—2.3	325
20	8 Leon	5.9	8 46.7	..	..	57	9 11.6	..	..	8
26	18 G.Libr	6.1	12 30.7	..	..	38	12 52.3	..	..	0
28	CD—27° 11076	6.5	7 4.1	..	..	40	7 25.3	..	..	1
28	135 B.Scor	6.0	8 47.9	—0.8	—0.8	142	9 53.7	—2.6	+0.9	254
OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′										
Mar. 15	47 B.Auri	6.1	6 14.8	—1.0	—0.5	68	7 13.6	+0.3	—2.0	302
18	*c* Gemi	5.4	0 49.0	—1.1	+2.6	61	1 56.2	—2.1	—1.8	318
19	γ Canc	4.7	5 47.3	—1.6	—2.0	129	7 9.1	—1.4	—1.8	296
20	8 Leon	5.9	8 3.4	—1.8	—1.3	98	9 7.3	—0.2	—2.5	334

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

Activities of some variables during 1950.

001046 X And. This star has been neglected during the last few years. No observations were made of the last maxima, from January through June. The period is 347 days, and the spectrum is Se.

001838 R And. Another Se variable, with period of 410 days, has been observed continuously since the middle of 1949.

002438a T Scl. A still stand in October, on the decreasing branch of the light curve.

004132 RW And. A maximum of magnitude 9.5 occurred in November, one magnitude brighter than the preceding maximum in September, 1949.

011041 UZ And. A bright maximum the last of September, a magnitude brighter than the previous one in November, 1949.

011208 S Psc. Very poorly observed.

013238 RU And. Observed range in brightness little more than one magnitude during the last two years.

013418' UV Cet. The "flare" star. On the evening of December 11, Robert Adams in Missouri observed it at maximum brightness, 10.2. Two hours earlier, William Galbraith in California, had observed it at normal magnitude, 11.9. Unfortunately, no more observations have been received for that night.

021403 Omicron Ceti. A faint, broad maximum occurred in August.

022813 U Cet. A maximum below 8th magnitude occurred the last of May, following one brighter than 7th magnitude early in October, 1949.

025050 R Hor. Our southern hemisphere observers furnish a complete light curve of this variable, which has a range of 7 magnitudes.

025751 T Hor. A maximum at about 8.8 magnitude occurred the middle of July. The two previous maxima were 9.5 magnitude in November, 1949, and 7.8 in April, 1949.

032335 R Per. A faint maximum of 9.5 magnitude was observed in the middle of November.

032339 RU Per. The observations of this star give little indication of variability.

032443 GK Per (Nova Per 1901). This old nova continues to vary. It increased from below 13th magnitude to about the 12th during October and November.

034625 U Eri. A faint maximum at 10th magnitude was observed the last of August.

040725 W Eri. A faint maximum at about 9.5 was observed in the middle of September.

043065 T Cam. A maximum a little brighter than 8, in the middle of April, and a minimum, nearly 14th magnitude, in the middle of October.

043*263* R Cet. Another southern variable which is observed throughout the complete range.

044*349* R Pic. A very shallow minimum was observed the last of September at 8th magnitude. The maxima on either side were at 7th magnitude.

050953 R Aur. A maximum at about 7.8 was observed the middle of October, following the usual still stand on the increasing branch of the curve. The preceding maximum was a magnitude brighter.

054319 SU Tau. This R Cor Bor-type star continues to remain at maximum, between 9th and 10th magnitudes, but small, rapid changes seem to be more frequent.

054615c RU Tau. Observations are very inconsistent. No well-defined maxima since 1947.

060547 SS Aur. This SS Cygni-type star has been very irregular. Maxima were observed around the following Julian days: 2,433,348; 3415; 3517; 3546; and 3624.

074*241* W Pup. The depth at minimum shows considerable variation. In the middle of March it was below 13th magnitude, the first of July it dropped to only 11.7, and in the middle of November it went to 12.5.

074922 U Gem. Only two maxima were observed during the year; one in the middle of May, and another around the 19th of October.

080*362* SU UMa. This U Gem or SS Cygni-type star was observed brighter than 12th magnitude only once during the year, about April 16.

103*270* RZ Car. Recent observations indicate a bright maximum (about 9th magnitude) in November. It is the first time since 1946 that it has been reported brighter than 10th magnitude.

103*769* R UMa. A bright maximum, about 7th magnitude, was observed the latter part of August.

115158 Z UMa. This interesting semi-regular variable (see light curve, *P. A.*, **58**, 307, June, 1950) shows almost perfect regularity throughout the last 3 cycles, with a period of about 200 days.

154615 R Ser. The maximum in the middle of June was a little below 7th magnitude, and the preceding one, July, 1949, was brighter than 6.

163*266* R Dra. Maximum at 7.7 magnitude in the middle of July was a magnitude fainter than the previous one in December, 1949.

164715 S Her. A faint minimum, below 13, in September.

172*486* S Oct. A very bright maximum, at 7.6, was observed the last of June. The preceding maximum was 10th magnitude in October, 1949.

180*222*a VX Sgr. After several years of comparative inactivity, VX Sgr decreased to fainter than 11th magnitude in November, 1949. There has been a steady increase during 1950 to about 7.5 magnitude.

190108 R Aql. A bright maximum, about 5.5 magnitude, was observed early in October.

193449 R Cyg. R Cygni continues to alternate high and low maxima. In June, 1949, maximum was at 8.5, and in July, 1950, it was up to 6.5 magnitude.

194632 Chi Cyg. This star also alternates high and low maxima. In the middle of October, it was about 4.8, a magnitude brighter than at the previous maximum.

195109 UU Aql. Four maxima were observed of this U Gem-type star during 1950, on JD 2,433,429, 3476, 3544, and 3600.

195656 RR Tel. Has decreased about a magnitude in a year, and was at 8.8 the first of December.

203501 AE Aqr. A report on this star was given by the Recorder at the Christmas meeting of the American Astronomical Society. Many maxima have been observed by the AAVSO members, at intervals of a little more than one day.

213843 SS Cyg. Six maxima were observed during 1950. The most recent one was a very narrow type, with maximum on December 27.

224552 DK Lac (Nova Lac 1950). The nova is now a little fainter than 11th magnitude.

Observations received in December, 1950. A total of 3,881 was received during the month from 52 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams	57	138	de Kock	125	673
Ahnert	13	106	Lacchini	12	13
Ancarani	28	51	LeVaux	72	80
Beardsley	2	2	Mary	21	21
Bicknell	9	109	Melville	14	22
Bogard	49	56	Meyer	6	6
Buckstaff	15	24	Miller	14	14
Cain	2	2	Milone	26	39
Charles	16	17	Morrisby	9	28
Cooke	29	41	Motley	10	11
Costello	4	4	Oravec	74	196
Cragg	100	106	O'Sullivan	14	31
Dafter	9	20	Parker	12	12
Darnell	1	2	Pearcy	22	22
Diedrich, DeL.	5	6	Peltier	30	50
Diedrich, G.	5	8	Renner	118	118
Drakakis	7	10	Rosebrugh	28	133
Escalante	151	265	Sill	10	12
Estremadoyro, V. A.	5	5	Taboada	157	228
Fernald	280	392	Thomson	3	3
Ford	16	16	Tifft	1	3
Galbraith	33	194	Upjohn	5	5
Greenley	68	102	Upton	17	26
Hartmann	178	218	Venter	37	56
Jerabek	5	7	Yamada	30	99
Kato	25	58	—		
Knowles	16	21	52 totals		3,881

Nova Search. Reports on the Nova Search Program were received during December from 8 observers, as follows:

Observer	Area	Nights	Mag.	Observer	Area	Nights	Mag.
Adams	16, 17, 31, 32, 39, 40	6	8	Drakakis	Dome	1	5
					Dome	1	3.5
	16, 17, 31, 32, 39, 40	1	7		North Pole	1	6
					North Pole	3	5
Diedrich, DeL.	40	1	6		North Pole	2	4
	94	1	3		1, 2, 8, 9	1	3
Diedrich, G.	Dome	3	2		1, 2, 3, 4, 8, 9, 10, 11	1	6
	56	1	5				
	56	1	4		3, 4, 8, 9, 10, 11	1	5
	78	1	6		3, 4, 10, 11	1	4

Observer	Area	Nights	Mag.	Observer	Area	Nights	Mag.
	8, 9	1	7		1	2	3
Rick	Dome	5	1		34	2	4
	18, 65	5	4		34	3	3
	63	1	4	Smith, F. W.	3, 4	6	6
Rosebrugh	Dome	3	3	Venter	110, 111, 121,		
	Dome	2	2		122	1	5
	1	1	4		118, 119, 133	1	4

January 15, 1951.

Comet Notes

By G. VAN BIESBROECK

The year 1950 has ended without further additions to the list of comets visible in the fall. Only one new comet was found during that year, namely, 1950 *a* (MINKOWSKI) which is still under observation. Its present appearance can be seen from Fig. 1 reproduced from a five-minute exposure on January 8 with the 82-inch reflector of the McDonald Observatory. It is now near perihelion (Jan. 15) but will continue to brighten up as it approaches the earth. On the original plate the diffuse tail is easily visible up to 15 minutes of arc from the head, in which center there is a sharp nucleus. The total magnitude was estimated as 11 but that figure is uncertain on account of the low altitude of the object in the morning sky. The following ephemeris by Bobone shows that the predicted course is southerly but that visibility will improve in the spring.

1951	α h m	δ ° ′	Mag.
Feb. 3	14 37.4	−27 38	
13	14 19.2	29 47	9.2
23	13 53.1	31 48	
Mar. 5	13 18.1	33 16	8.9
15	12 34.9	33 38	
25	11 48.2	32 27	8.9
Apr. 4	11 04.7	29 49	
14	10 28.8	26 24	9.2
24	10 01.9	−22 55	

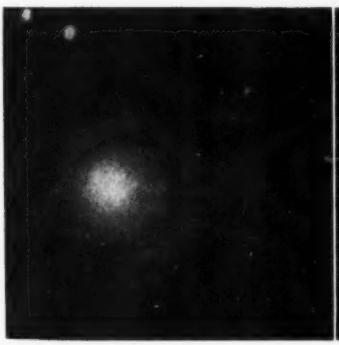

FIGURE 1
COMET MINKOWSKI
1951, January 8

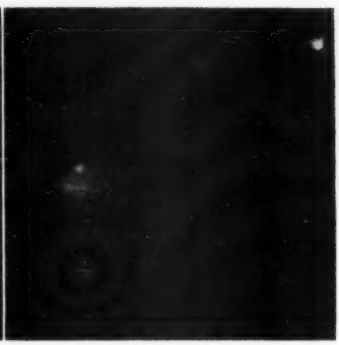

FIGURE 2
PERIODIC COMET ENCKE
1951, January 10

With larger instruments a number of faint comets found last year can be followed but none are in reach of ordinary instruments. The only exception is periodic comet Encke which is expected to brighten up before long. Fig. 2 is obtained from a 10-minute exposure on January 10 with the 82-inch McDonald Telescope. The comet appears as an elongated nucleus which spreads out in a short stub of fan-shaped tail. The total brightness was about 14th magnitude on that date. As the comet moves into the western sky it should become brighter than magnitude 8 and therefore become visible in a small telescope before it is lost in the twilight next March. The following ephemeris should enable observers to watch this well-known object and make estimations of its brightness which is best done by comparing it with known neighboring stars the eyepiece being moved out of focus so that star and comet have nearly the same appearance.

1951	α h m	δ ° ′	Mag.
Feb. 3	23 39.4	+ 6 44	
13	23 56.3	8 01	
23	0 14.3	9 04	8.4
Mar. 5	0 27.8	+ 8 31	

After this date the comet passes between us and the sun and reappears in the morning sky in April. However, it will be already fainter and losing in brightness by that time.

With its usual regularity the British Astronomical Association has published the *Handbook for 1951* in which its computing section has provided ephemerides for the periodic comets expected this year. They are in order of the date of their perihelion passage:

Encke	1951 Mar. 16
Neujumin 3-1929 III	May 15
Kopff	Aug. 11
Pons-Winnecke	Sept. 9
Tempel	1951 Oct. 25
Schaumasse	1952 Feb. 9
Grigg-Skjellerup	1952 Mar. 11

To these are to be added periodic comets Oterma 1942 VII and Schwassmann-Wachmann Nr. 1, 1925 II, which both have such a small eccentricity that they can be observed every year.

January 11, 1951, Fort Davis, Texas.

General Notes

Dr. Daniel Buchanan, Professor Emeritus of Mathematics and Dean Emeritus of the Faculty of Arts and Science of the University of British Columbia, died in Vancouver, British Columbia, Canada, on 1950 December 1, at the age of 70 years. Dr. Buchanan, who took his Ph.D. degree at the University of Chicago in 1911, under Dr. F. R. Moulton, was a specialist in mathematical astronomy and celestial mechanics.

Mr. Harry B. Rumrill, a well-known amateur astronomer, a frequent contributor of papers to this journal, and a past president of the Rittenhouse Astronomical Society of Philadelphia, died at his home in Berwyn, Pennsylvania, on January 23, 1951. Mr. Rumrill had built an observatory to which he gave the

name Tredyffrin Observatory. Since his retirement as an accountant for the Pennsylvania Railroad Company in 1932, Mr. Rumrill has devoted himself assiduously to observing the changes on the sun and other astronomical phenomena.

The Rittenhouse Astronomical Society, of Philadelphia, held its January meeting on Friday evening, January 12, 1951, in the Little Theatre of The Franklin Institute. The speaker, Dr. I. M. Levitt, Director of the Fels Planetarium, used as his topic "Planetarium Facts and Fancies."

Provisional Sunspot Numbers for December, 1950*

1	82	11	100	21	7
2	80	12	115	22	0
3	77	13	94	23	13
4	75	14	79	24	31
5	61	15	59	25	39
6	46	16	42	26	56
7	85	17	26	27	58
8	108	18	19	28	35
9	94	19	7	29	41
10	94	20	0	30	23
				31	43

Mean Value for December
R = 54.5

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Summary of Sunspot Observations at Mount Holyoke College, 1950

Month	No. of Obs.	North of Equator No. of Groups	North of Equator Av. Lat.	South of Equator No. of Groups	South of Equator Av. Lat.	Av. No. Groups at one Obs.	New Groups
January	14	25	+11°1	7	−11°6	6.8	29
February	20	20	12.8	11	11.5	6.4	31
March	24	27	15.4	17	13.3	7.8	40
April	20	18	15.1	12	12.3	5.8	24
May	22	30	14.3	15	14.1	6.6	38
June	26	24	12.0	7	17.7	4.8	30
July	26	15	12.2	11	14.8	5.0	23
August	24	7	13.9	13	14.3	4.8	17
September	22	10	14.2	7	15.7	2.8	15
October	27	12	15.7	7	9.0	3.1	17
November	22	8	14.5	9	11.4	3.8	13
December	20	6	+15.8	6	−13.0	2.6	7
Totals	267	202		122			284

Average number of groups at one observation..... 4.94
Average latitude of 182 groups north of the equator.....+13°59
Average latitude of 102 groups south of the equator.....−13°38
Number of days without spots..... 4

The figures noted here indicate a sharper drop in spot-activity from 1949 to 1950 than from 1948 to 1949. If last year's report tended to show a plateau on the curve of descent, it may be said that by the end of 1950 the curve had reached approximately its expected level had the plateau not existed. This is shown both in the average number of groups per observation and in the number of new groups. The average number of *spots* per observation (deduced from a total of 6750 counted in 1950) showed its plateau earlier in the interval 1947 to 1950 (*cf.* the respective averages 67, 64, 51, 25).

Of the 284 groups studied, 40 were under observation over a period of ten or more days, 48 on a single day only. Spot activity was far greater north of the equator than south of it. On May 11 a spot (classified J) appeared at solar lat. +42°, long. 348°. Otherwise, 10 groups were noted beyond 25° north, and 4 beyond 25° south. A number of these were returns of the same group.

No spots were to be seen on Dec. 19 and for several days following. Previously the "clean" sun had not been seen since 1945 Aug. 22, an interval of 1945 days. The previous interval during which the sun was observed as continuously spotted lasted 2003 days (1935 Oct. 9 to 1941 Apr. 3).

The principal observers were, chronologically, Mrs. K. Tinker, Miss Farnsworth, and Miss W. Sawtell. Others who assisted were Miss J. Hornor, Miss A. Frear, Miss R. Botley, and Prof. and Mrs. J. C. Hall.

ALICE H. FARNSWORTH.

John Payson Williston Observatory, Mount Holyoke College, South Hadley, Mass., January, 1951.

Book Reviews

Der Sternenhimmel, (1951), by Robert E. Naef. (Published by H. R. Sauerländer & Co., Aaran, Switzerland.)

This publication being a year book is much the same in its arrangement from year to year, the specific items varying in accordance with the requirements of the year in question. Mention of the edition for 1950 was made on page 197 of the April (1950) issue of this journal, to which the attention of the reader is directed for a description of the current edition. C.H.G.

The Conquest of Space, by Willy Ley, paintings by Chesley Bonestell. (The Viking Press, New York. $3.95.)

This book, published in 1949, is unique. This is a natural consequence of the fact that it deals with ideas which are only beginning to become current. Rocket propulsion in recent years has given great impetus to the thoughts that are suggested by the title of this volume. Any such considerations immediately call for a comprehension of certain basic astronomical facts. The writer shows that he is at home in this field. His earlier works, "Rockets and Space Travel" for instance, show that he is equally well informed regarding the mechanical technicalities involved. His writing, therefore, makes the reader feel that the subject is worthy of careful thought, and that it is not only the fiction of an overactive imagination.

The book is divided into four chapters with titles as follows: "Four, Three, Two, One—Rocket Away," "Target for Tonight: Luna!", "The Solar Family," and "Vermin of the Skies." They deal, in order, with high-altitude rocket experimentation, the circumstances attendant upon a trip to the moon, the principal objects in the solar system, except the sun, and, last, the asteroids or planetoids. The author has a style which makes the reading of factual material a delight. The pages are not simply hard scientific facts devoid of humor, but are alive with the personality and enthusiasm of the author.

An important aspect of this volume is its illustrations. In the introduction Mr. Ley introduces Mr. Bonestell, and explains his qualifications for doing work such as we find here. There are numerous charts and drawings, and numerous paintings reproduced in color. These too, like the text, are not imaginary views, but

are made to conform with accepted facts. They are, it is true, for the most part pictorial representations of scenes which have never been viewed with human eyes, but they do not contradict known characteristics.

It is a very modern book which is sure to leave a lasting impression upon the mind of the reader. C.H.G.

Sterne und Sternsysteme, by Dr. Wilhelm Becker, Wissenschaftliche Forschungsberichte Bd. 55. Second edition 1950. Illustrated. (Verlag von Theodor Steinkopff, Dresden und Leipzig. 418 pp. 30 DM.)

The first edition of Becker's book was printed in 1942 and sold out in a short time. After the war this edition was lithoprinted in 1946 by Edwards Brothers Inc. (Ann Arbor, Michigan) and made available to the American public. In 1950 Becker published the revised second edition of his book. The photographs are printed on a better kind of paper now.

The author considers this book as intermediate between a real scientific and a popular book, and with these limitations in mind it is an excellent book. A student in Milky Way research has to read this book first because this will help him in understanding the problems involved which he will encounter in more advanced textbooks. The astronomer will find the many references in this book of much value.

The first eight chapters of the book deal with our Milky Way system and consider properties of stars, variable stars, double stars, star clusters, interstellar material, motions and distances of stars, distribution in space, kinematics and dynamics of the Milky Way system.

The last five chapters deal with extra-galactic nebulae and consider star-systems, different types and their properties, distance determination, radial velocities in connection with distances, apparent and space distributions.

The author included much recent literature to bring the book up to date and the value of the book increased proportionally. In the English language a book of this kind is still lacking and a translation should be worthwhile.

A few omissions were noted. The author does not mention the work of A. J. Wesselink and A. van Hoof on the δ Cepheid problem. Table 66 on page 237 giving the mean parallaxes for apparent magnitude groups is out of date. For the brighter stars the data of J. P. van Rhijn are still the best. For fainter stars one might take the revised values derived by A. N. Vyssotsky and for the faintest stars the data obtained by the reviewer combined perhaps with the earlier values of J. H. Oort and A. van Hoof. The agreement between the mean parallaxes of Vyssotsky and of the reviewer in the overlapping magnitude groups is excellent, although they were determined by entirely different methods.

L. Binnendijk.

Goodsell Observatory, Carleton College.

Editor's Note. Attention is called to an obvious error on the front cover of the January issue. The volume number for 1951 is LIX *not* LVIX.

POPULAR ASTRONOMY

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